A HAND BOOK

OF THE

REFRACTION OF THE EYE

ITS ANOMALIES AND THEIR CORRECTION

BY

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TO

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PROFESSOR OF OPHTHALMOLOGY AND OTOLOGY IN THE
UNIVERSITY OF MICHIGAN, WHOSE UNCEASING
AND ENERGETIC WORK HAS DONE SO MUCH
TO ELEVATE THE STANDARD OF OPH-
THALMOLOGICAL INSTRUCTION AND
TO WHOM I AM INDEBTED FOR
MY ADVANCEMENT IN
THE SCIENCE, I
DEDICATE THIS
VOLUME.

PREFACE.

The object of this little volume is to present, in a plain and practical form, an explanation of the anomalies of refraction and their correction.

It substantially embodies the instruction given to the demonstration classes in the University of Michigan, and while it is intended, primarily, to facilitate the work of Junior students in preparing the subject, the perusal of its pages may prove of benefit to other readers.

It has been thought unnecessary to go into the more intricate and scientific demonstrations of the refraction of light, which are, happily, not of an extremely practical nature.

The chief aim has been to go explicitly into every practical detail so that the beginner may not be lost in the labyrinth, and it is hoped that those more advanced may not tire of the minutia.

It has been compiled during the hours which could be spared from active duties, and though the writer has sought to be exact in all his assertions, an occasional inaccuracy may have inadvertently crept in. Any emendations which my co-laborers may propose will be gratefully received and noted in a subsequent issue.

I am under many obligations to my congener, Dr. C. B. Bliss, who has assisted me very materially in compiling and arranging the contents.

CONTENTS.

CHAPTER I.

Lenses, Refraction of Light and the Formation of Images.

REFRACTION OF LIGHT.

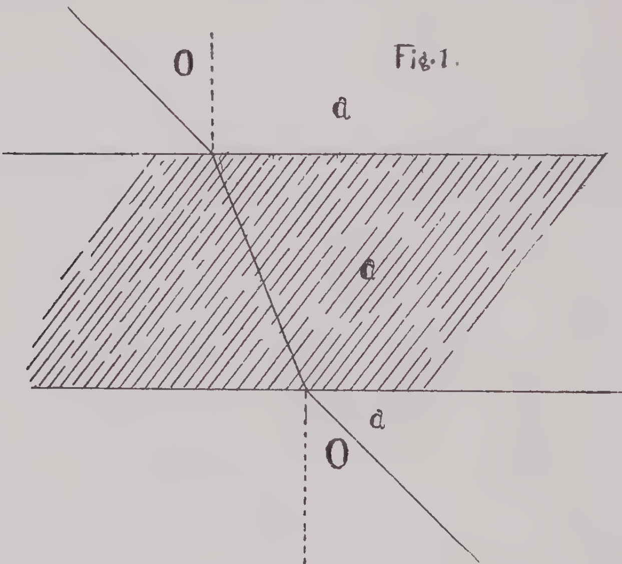
Rays of light are refracted when they pass from one transparent medium into another of different density, unless they fall perpendicularly, to the surface of the second medium. The deviation of rays passing from a vacuum into air is represented as 1. The ordinary spectacle or crown glass lens is represented by 1.50; the pebble or so-called optician's glass by 1.66. When a ray of light passes from a less to a more refractive medium the deviation is toward the perpendicular. When a ray of light passes from a more to a less refractive medium the deviation is away from the perpendicular, and to the same extent providing the first and third media are equal.

In Fig. 1—A, equals air; A' equals glass; Angle O equals angle O'.

From this it is seen that rays are restored to their original direction, if the sides of the medium of greater refraction are parallel; but if the sides of

this medium form an angle (the angle of incidence and emergence being equal), there must be an angle formed by the intersection of the ray of incidence and the ray of emergence if continued.

In Fig. 2—The deviation shown by the angle 0 is equal to about one-half the refraction angle x in a crown glass prism. $B.\ C.\ B'.$ is an angle which

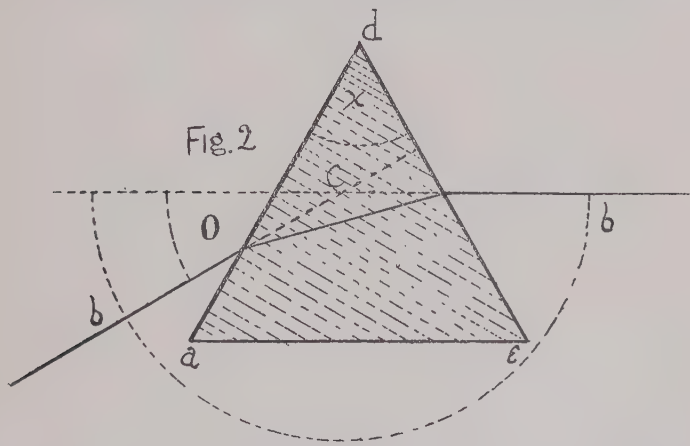


would not occur if the side a, d and d, e were parallel. For lenses of small determination the refraction of rays is the same at all angles of incidence, if at the same distance from the principal axis.

In Fig. 3 angle $a\ b\ c$ in A equals angle $a\ b\ c$ in B, and angle $a\ b\ c$ in A equals angle $a\ b\ c$ in C,

and the angles *a b c* are equal in each case. Hence the nearer the object the farther the image from the lens. Each transparent medium refracts light but not equally. Opticians call those of higher refractive media, denser media, and those of lower refractive media, rarer media.

In Fig. 4—*A* equals air: *A′* equals water. The angle *A*, *B*, *D*, is the angle of incidence, and *C*, *B*, *E*, is the angle of refraction. The *A*, *B*, *D*,



is to the angle *C*, *B*, *E*, as the propagation of light in *A* is to the propagation of light in *A′*.

Rays passing through the principal focus or optical centre of the lens, Fig. 5, are not refracted.

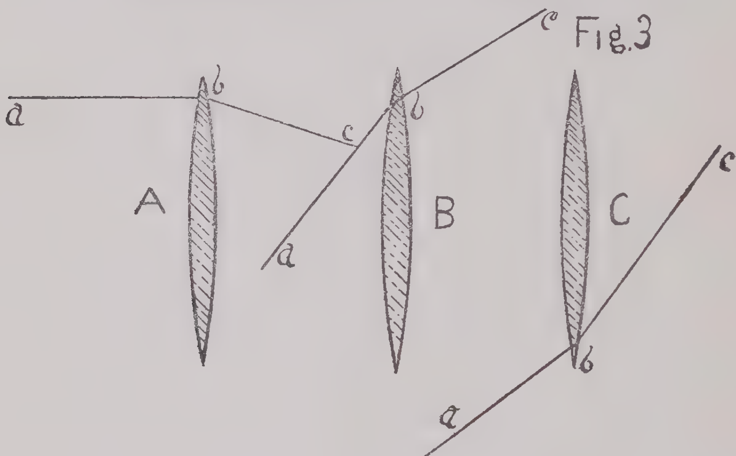
Every incident ray refracted by the first surface in such a way as to pass through the optical centre of the lens emerges from the system in a

direction parallel to the path of the primitive or incident ray.

In Fig. 6—*A*, *B* and *C D*, are parallel lines.

From the foregoing it will be seen that the image formed at or behind the principal focus of a convex lens, on the opposite side to the object will be a positive, real and inverted image. See Fig. 7.

Fig.3

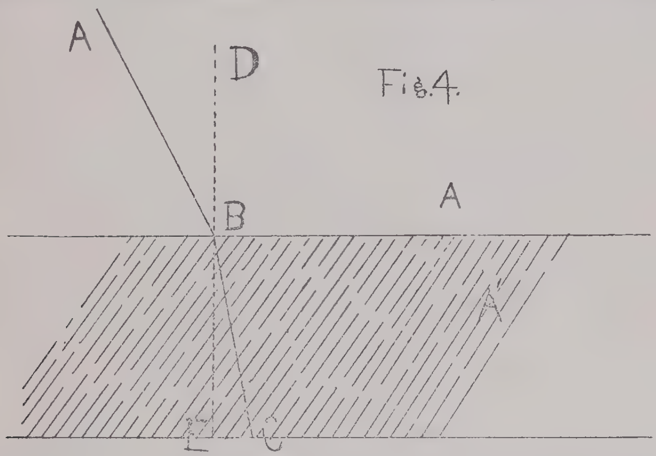


Hence the nearer the object is to the lens the farther the image recedes from the lens and the larger the image. As a matter of fact when the image is at a distance of double the focal distance of the lens the image is the same in size as the object. In a positive meniscus the relation of distance, position, and size are determined by the same method as in a biconvex lens, but there is no spherical abberation, parallel rays of light being

brought to a focus at exactly a common center. All lenses of low power are ground in menisci; the only disadvantage being that in high power they are too heavy for practical use.

MEASURING LENSES.

The stronger a lens is the more is light refracted by it. The greater the deviation given to par-



allel rays by a lens the nearer is its focus to the lens and the less its focal distance. The focal distance, of a lens is determined by dividing one hundred, (which is the number of centimeters in a meter), by the number of dioptres of the lens. A one dioptre lens has a focal distance of one meter or one hundred centimeters. A two dioptre lens lens has a focal distance of one-half a meter or fifty centimeters. A ten dioptre lens has a focal dis-

tance of one-tenth of a meter or ten centimeters. Hence the refractive power of a lens and its focal distance are inversely proportionate to each other. The number of dioptres of a lens may be found by using the one meter as a numerator and the focal distance expressed in meters as a denominator. Suppose a lens to have a focal distance of forty centimeters:

$$\frac{1}{.40} = \frac{100}{40} = 2.50 \text{ dioptres.}$$

A prism optically considered may be said to be a transparent body having two large flat surfaces

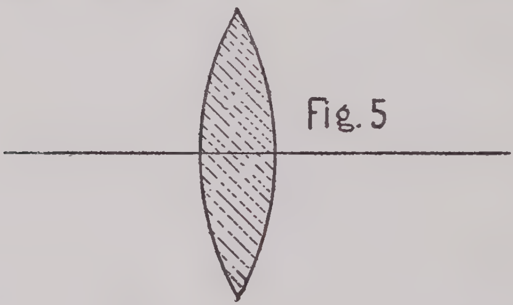
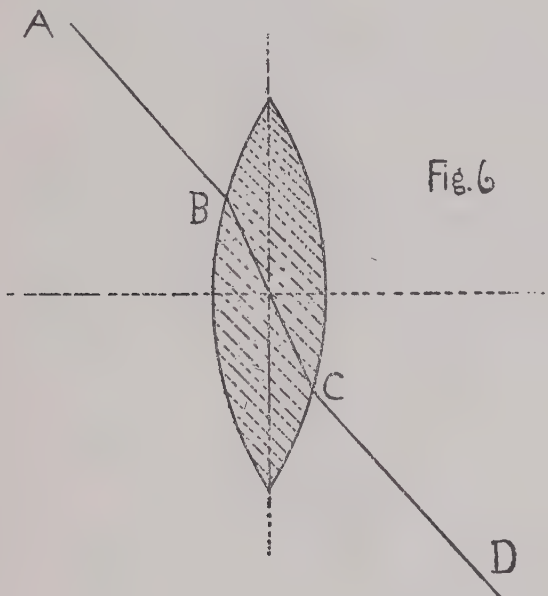


Fig. 5

which are not parallel, with two equal parallel triangular ends, a base and an apex. An object seen through a prism is seen displaced toward the apex of the prism. The amount of displacement varies directly as the size of the refracting angle of the prism, and the object seen, appears to come from the position indicated by the rays of light, after

they leave the prism. This fact is utilized to remove the point of fixation, or in other words, to lesson the amount of convergence demanded to produce binocular vision; to relieve diplopia when caused by insufficiency of the ocular muscles; to test the strength of the extrinsic eye muscles, and to test malingerers.

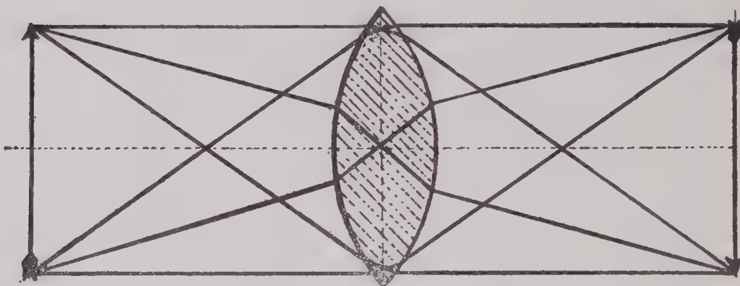


In Fig. 8—*A* and *B* parallel as incident rays are parallel as emergent rays.

The relative direction of a number of rays is not changed by a prism. All rays are deflected

toward the base by a prism. If parallel as incident rays they are parallel as emergent rays.

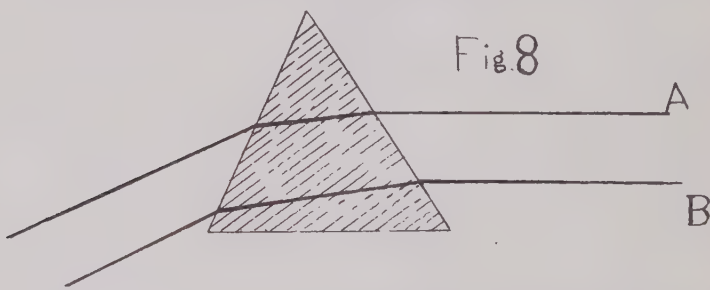
Fig. 7



In Fig. 9—*A* represents the object and *B* the apparent object after the light has passed through a pair of prisms which are placed in front of the eyes, base in.

In the eye the objects are seen to be in the direction from which the rays of light enter the eye.

Fig. 8



Of the positive and negative lenses the following varieties are common:

In Fig. 10—*A* is a biconvex lens. *B* is a

plano-convex lens. *C* is a convergent meniscus or a convergent periscopic lens. *D* is a biconcave lens. *E* is a plano-concave lens. *F* is a divergent meniscus or a divergent periscopic lens.

A, *B* and *C* render rays of light falling on their surface at different sides of the principal axis more convergent and are called positive or plus

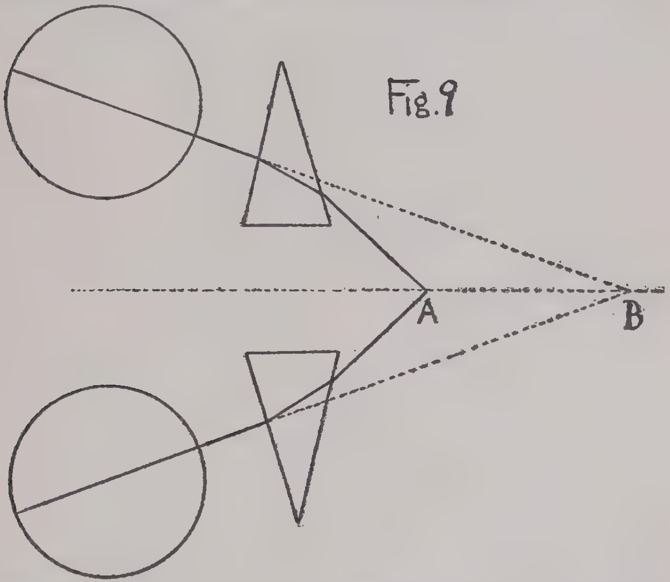


Fig. 9

lenses. And *D*, *E* and *F* render rays of light falling on their surface at different sides of the principal axis less convergent and are called diminishing, minus or negative lenses.

The second or posterior focus of a convex lens is the point at which rays of light are focused,

which, when incident were parallel to its principal axis. As a matter of fact this focus varies somewhat, as rays entering the lens farther from its principal axis are refracted more than those entering nearer the principal axis, and from this fact results spherical aberration.

In Fig. 11—*a* is the focus of rays *d*, falling on the periphery of the lens. *b* is the focus of rays *e*, falling on the lens nearer its principal axis.

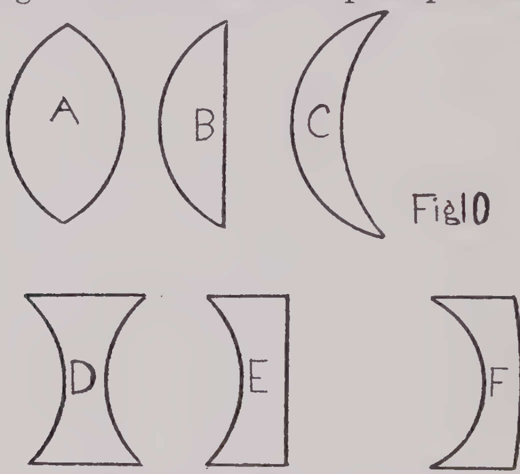


Fig10

The refracting power of a lens varies inversely as its focal length. In the human eye the iris is hung in such a manner as to shut off rays of light that would otherwise pass through the periphery of the lens. Again, the centre of the nucleus of the lens is denser than the peripheral part of the nucleus. By these two phenomena the spherical

aberration in the eye is partly overcome, but when by the use of a mydriatic the pupil is well open, and rays of light pass through the periphery of the lens, some spherical aberration results and the patient complains of a hazy appearance of the letters on the test card, notwithstanding the fact that normal visual acuity is obtained.

Landolt calls attention to an interesting fact. At 5 metres distance a myope of .40 of a dioptre

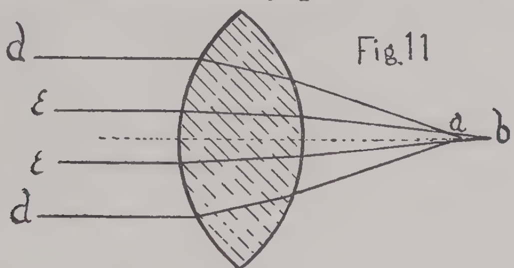


Fig. 11

is regarded as an emmetrope, whereas a myope of .09 of a dioptre is considered as a hyperope.

The myopia must exceed .40 of a dioptre before he will see better with a — .25 dioptre glass than with his naked eye, because with this glass, circles of diffusion are smaller than those produced by the eye alone; again as soon as the myopia falls below .09 of a dioptre, vision will be improved by a +.25 of a dioptre glass, because the circle of diffusion becomes smaller than without the glass.

CHAPTER II.

The Emmetropic Eye.

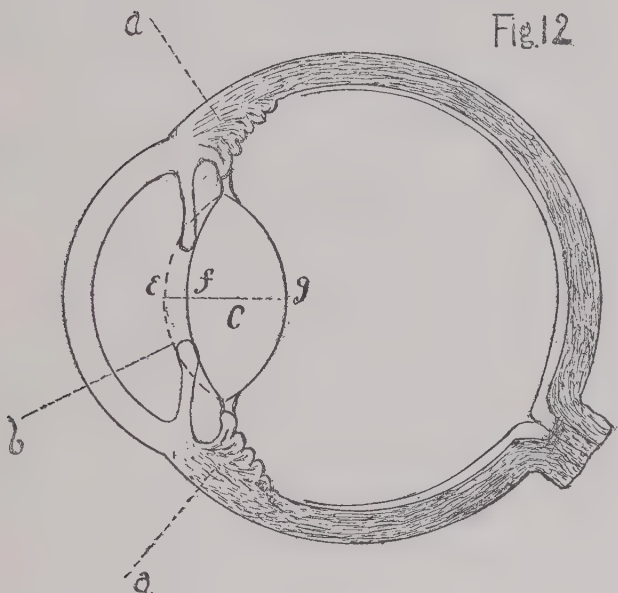
The camera is often used to represent the human eye, and the two are similar in many respects. By the system of refractive media, an inverted image of objects that appear within the visual field of the eye, is produced on the retina. So perfect is the construction of this human camera, that an iris is found hung in front of the crystalline lens to exclude the peripheral rays of light, which on passing through the periphery of the lens, would produce spherical aberration as explained in the preceding chapter. (See Fig. 11).

We find the sensitive plate or retina provided with a pigmentary layer, to lessen the reflection of light, by the absorption of rays that would otherwise be reflected, and being reflected would produce a certain amount of dazzling under all circumstances.

With the camera the operator must move the sensitive plate nearer the lens the farther the object is placed from the lens; and the farther from the lens the sensitive plate is situated, the nearer must be the object to be photographed.

This adjustment is made in the eye by the contraction of the ciliary muscle and corresponding thickening of the lens when near objects are fixed.

Fig. 12



A represents the ciliary muscle in a state of rest and that part of the line *f*, *g* of the line *e*, *f*, *g* indicates the antero-posterior diameter of the lens *c*. The dotted line *b* represents the anterior boundary of the lens *c* when the ciliary muscle (*a*) shall contract. The antero-posterior diameter of the lens *c* would then be indicated by the line *e*, *f*, *g* and the refracting power of the lens would be increased.

This phenomena of changing the focus of the eye is called accommodation and is treated of more fully under Chapter III. It is also necessary in order to have a single image perceived, when both eyes are used, that the image be formed in corresponding parts of each retina. The region of the macula lutea is, as we know, the most sensitive field in the retina, and hence the most desirable for use when the best vision is required. When fixing distant objects the position of each retina is such that the image falls on both maculæ at the same time; but when a near object is fixed, unless the eyes could be rendered more convergent, it is evident that neither image would fall directly on the macula.

The turning of the eyes inward, to that extent that the image may fall on both maculæ, when a near object is fixed, is called convergence. As one must both accommodate and converge to fix near objects and obtain a single image, it would seem that a co-ordination between these two functions would be imperative. It is, and whenever from causes later considered this co-ordination is interferred with, much annoyance results. From anatomy we have learned that the centers for accommodation and convergence are very intimately connected and situated upon the floor of the fourth ventricle. The more anterior nuclei govern the ciliary and sphincter pupillæ muscles and just posterior to

them are the nuclei governing convergence. Indeed so closely are they placed that they are simultaneously set in action by any stimulus, yet the action of either center may be partly or quite inhibited.

When the emmetropic eye is in a state of rest (that is when the accommodation is suspended), parallel rays of light falling on the cornea are focused on the retina. Now if the refraction of the eye, when the accommodation is at rest, is such that parallel rays of light are not brought to a focus until after they reach the retina (in other words if the static refraction of the eye is weaker than normal), the eye is called hypermetropic. If, on the other hand, the refraction of the eye, when the accommodation is at rest, is such that parallel rays of light falling on the cornea are brought to a focus, too soon, or before they reach the retina (in other words if the refraction is relatively too strong), the eye is called myopic. If one meridian refracts light more strongly than another meridian in the same eye, the eye is called astigmatic.

As physicians we have also to deal with many troubles growing out of deficiencies of the extrinsic ocular muscles, both when they are doing their work in helping produce binocular vision under protest (insufficiency), and when having worked along at an overtask they abandon all hope of doing their work and succumb to the strength of their antagonist allowing an actual deviation

(strabismus). In either the refractive or muscular phenomena a large per cent. of all eyes possess some anomaly.

By the refraction of the eye is meant the amount of deviation expressed in dioptres that rays of light undergo when passing through the eye. By use it has been commonly accepted to mean the abnormality of the refraction existing in a given eye, as + 1.00 dioptre is given as the refraction of an eye, that is one dioptre hypermetropic.

Let us hastily consider the refracting surfaces and media of the eye. The first refracting surface met with is the cornea, and the first refracting medium, the aqueous. The cornea is the most important of the surfaces to be considered, not because its convex surface has a shorter radius than its concave, but because it separates two media (air and aqueous), the refractive indices of which differ more than any other two contiguous media to be considered.

The posterior surface of the cornea is more curved than its anterior surface, and hence the cornea forms a divergent meniscus, but because it separates these two greatly different media, this may be practically overlooked. Helmholz gives as the average radius of the cornea 7.829 millimeters; Donders 7.6 millimeters.

Granting the index of refraction of air as 1.00, the index of both aqueous and vitreous may be

considered as 1.34. The crystalline lens is about 3.75 millimeters thick and has a radius on its anterior surface of about 7.5 millimeters; its posterior surface presents a radius of about six millimeters. The cortical substance of the crystalline, forms many divergent menisci—(their concave surfaces having a shorter radius than their convex surfaces), they also are more strongly divergent in their action near the circumference of the nucleus of the lens which is a convex lens of very high refractive power. This greater divergence given to the rays (by the cortical divergent menisci), farther from the principal axis of the eye, beautifully assists in correcting what spherical aberration remains uncorrected. This is especially of service when rays enter the eye at a considerable angle to the optic axis. The construction of the crystalline is then infinitely superior to an ordinary convex lens, in that it produces a more distinct image. Taken as a system it is evident that the dioptric system of the eye is a convex lens.

The second or posterior focus is about 23.00 millimeters back of the cornea and represents the length of the emmetropic eye. The first principal focus is situated about 14.00 millimeters in front of the eye.

The conjugate foci may be defined as two points situated one in front of the eye and the other behind the lens on the retina. The first point

being in such a position that rays of light emanating from it are brought to a focus at the second point.

If an object from which an image is to be formed be situated on the principal axis of the eye the rays given off will be focused on the principal axis behind the crystalline. If the object be situated at a given distance from the principal axis of the eye, the image will be formed upon a secondary axis or on a straight line drawn from the object through the nodal point. All lines of secondary axes cross at nearly the same place, about 7 millimeters back of the cornea. Hence images will be inverted relative to their object, and many images may be formed at the same time. In the emmetropic eye the retina is found at the focus of the dioptric system of the eye. The point for which the eye is focused when at rest is called the Punctum Remotum. The point for which the eye is focused during maximum accommodation is called the Punctum Proximum. The Punctum Remotum for the emmetrope is infinity and for the hyperope beyond infinity. For myopes the Punctum Remotum is a finite distance.

In the study of refraction we have the optic apparatus of the eye to consider in a state of repose and in all degrees of variation of accommodation, depending upon the position of the object fixed. An eye, whose refraction when in a state of

rest does not bring parallel rays of light to a focus on the retina, is called ametropic. Hence the term ametropia is applied to the eye where the retina is not situated at the focus of the dioptric system of the eye.

CHAPTER III.

Visual Acuity, Accommodation and Convergence.

VISUAL ACUITY.

The visual angle is formed by the rays of light which pass from the terminal points of the object in view, through the nodal point of the eye, to the retina. It is the measure of visual acuity. In forms of ametropia and in diseases of the fundus, as well as in old age, the visual acuity is decreased. Visual acuity, as spoken of, is used relative to the central vision, as the macula is the most highly sensitive part of the retina. Many persons have visual acuity above normal, while some emmetropes have visual acuity somewhat below the normal. Visual acuity is measured by measuring the angle formed by the rays which pass from the extremities of the object fixed through the nodal point to the retina; and by long experiment it was determined that a normal eye should see the object forming an angle of one minute as above stated. Hence it is said that a person, who cannot receive a distinct visual impression by an object of proper size and at proper distance to form such an angle, has not

normal visual acuity. The visibility of a small object depends greatly on its luminosity. Hence figures with regular or parallel parts, or a number of dots printed black (which remains always of equal luminosity), on a white back ground should be used in testing visual acuity, and the distance at which the separation of the dots or the peculiar construction of the figures can be determined, will give a correct measure of visual acuity.

Mr. Snellen has constructed a card of letters arranged in different rows, each row of a different size, and the number of feet at which a five minute angle is formed written over each row. If the patient at twenty feet sees the line which at that distance gives a one minute angle by each extremity of the letter, or a five minute angle with the whole letter, the visual acuity is normal or $\frac{20}{20}$. If he sees only at twenty feet a line that forms a five minute angle at forty feet, the visual acuity is $\frac{20}{40}$.

The testing of near vision is made by using very small print, and here the smallest type that can be read is determined; also the distance of space through which it can be read.

The nearer the object is approximated to the eye the larger is the retinal image. The ratio is direct and therefore the smaller the object the nearer we bring it to the eye; however, persons with very greatly diminished visual acuity always bring objects very near to the eye in order to get a

large retinal image, as for instance, the myope and the absolute hyperope (the former produces rays of light divergent enough from the object to adapt them to the refraction of the eye, while the latter has the sole object of increasing the size of the retinal image). Of course the nearer the object the greater must be the accommodation used to get a distinct retinal image. Hence we determine the amount of presbyopia by finding the amount of accommodation yet available.

The myope, whose near point is moved in toward the eye, can bring objects very close and get large retinal images and they are accorded to have excellent eyesight, until a chance for comparing distant vision occurs.

In testing the visual acuity when the large letters on the card cannot be told, the patient should be requested to count the fingers held in front of the eye; if he is unable to do this the hand or any large object may be used for the test; if nothing can be seen and there still remains a perception of light, the patient is said to have quantitative vision. Proper illumination must be preserved in all tests for visual acuity, and in cases where reports are required for the navy, railroad service, etc., visual acuity should be taken when the accommodation is at rest and the correcting lenses are on. When the pinhole disc helps the visual acuity it is a strong indication that the trouble is a refractive anomaly;

when it does not improve the visual acuity of a person that cannot read $\frac{20}{20}$ it strongly points to some trouble other than a refractive anomaly.

ACCOMMODATION.

Every one must have observed that it is easier to look at an object five feet distant than to fix one five inches away. Why is this? Because in order to get a distinct image of the near object in one eye, the work of accommodation must be called into play. When both eyes participate, convergence and accommodation must act together. This work of accommodation requires a continuous contraction of the ciliary muscle in order to increase the index of refraction of the dioptric system of the eye. This continual effort on the part of the ciliary muscle causes many troubles which are summed up under the head of accommodative asthenopia. When an object five feet distant is fixed we cannot distinctly see the one five inches distant. Why? Because the eye being in focus for the far object has not at that time, enough refractive power to bring the rays of light from the near object to a focus when they reach the retina.

These rays not being completely focused form a blurred or diffusion circle image, which image imitates the contour of the pupil. (See Fig. 12.)

If the emmetrope wishes to see anything 40 centimeters from the eye he must use 2.50 dioptres

of accommodation if he obtain a clear image. If the object be 10 centimeters from the eye he must use 10. dioptres of accommodation. When the image approaches so near the eye that the entire accommodation cannot bring the focus, of the rays of light, from the image, on the retina; or when the eye is hyperopic to such a degree that the error cannot be corrected by the action of the ciliary muscle, or when the distant object is viewed by the myope, indistinct vision results.

All indistinct vision from ametropia is due to diffusion circles, and the diffusion images are larger as the retina is farther from this point of focus and as the pupil is larger. When at rest the emmetropic eye is adjusted so that parallel rays of light falling on the cornea will come to a focus on the retina. Accommodation depends on the elasticity of the lens substance owing to which the latter always tends to form a sphere. The capsule is attached by Zinn's zonula to the ciliary body. The zonula is placed continually on the stretch, exerting a uniform traction and keeping the lens flattened. When the annular layer of fibres of the ciliary muscle contracts the circle protecting the tension of the zonula is lessened, and the tension thereby taken off the capsule, the lens at once becomes thicker, and consequently refracts light more strongly. Hence the more this process goes on the more divergent are the rays of light

that can be focused on the retina. The longitudinal fibres of the ciliary muscles are attached in the sclera near the corneal margin, and to the movable choroid; by the contraction of these fibres the ciliary body is drawn forward and the action of the annular fibres assisted. As the lens becomes more convex the equatorial diameter decreases and a way is made for the advancing ciliary body.

The anterior surface of the lens is more affected by the accommodation than the posterior surface, as the anterior surface can more easily invade the aqueous than can the posterior surface lying in the fossæ patelliformis invade the vitreous. The sphincter pupillæ and the internal recti generally contract simultaneously with the ciliary muscle, their centres being very closely connected in the anterior part of the oculo-motor tract. When the ciliary muscle is at rest and the lens has its minimum convexity, the eye is adjusted for its far point. When the greatest possible contraction of the ciliary muscle has taken place and the lens has assumed its maximum convexity, the eye is adapted for its near point. The far point or Punctum Remotum of all emmetropic eyes is at infinity. The near point or Punctum Proximum will depend largely on the strength of of the accommodation. This Punctam Proximum may be determined by noticing the distance at which an eye can read the smallest letters, and by

expressing this distance in centimeters or better millimeters. The space between the Punctum Remotum and the Punctum Proximum is the range of accommodation and is no criterion of the amount of work done by the eye in adapting itself to the Punctum Proximum from the Punctum Remotum. The region of accommodation is a term used to express the distance of the entire range of accommodation from the eye, thus the region of accommodation of a myope is said to be closer to the eye than that of an emmetrope, as his Punctum Proximum and Punctum Remotum are closer to the eye. The difference of the amount of the index of refraction of the eye between its Punctum Proximum and its Punctum Remotum equals the amplitude of accommodation. If we look at infinity and then at an object ten centimeters away, it requires some effort to fix the near object. Now, if we look from the object ten centimeters distant to one five centimeters distant, we find that the latter change of fixation caused a greater exertion than the former, whereas in the former instance the refraction of the eye was changed from infinity to fixation at ten centimeters, while in the latter the refraction was only changed from a fixation at ten centimeters to a fixation of five centimeters. It is evident then that the range of the accommodation cannot form a basis for the determination of the the amplitude of accommodation. The amplitude

equals the Punctum Remotum minus the Punctum Proximum expressed in dioptres. To determine the amplitude of accommodation in emmetropia divide the number of centimeters in a meter by the Punctum Proximum expressed in centimeters (the Punctum Proximum of an emmetrope expressed in centimeters, we will suppose in this given case to be ten centimeters). Divide one hundred, or the number of centimeters in a meter, by ten, which is the near point expressed in centimeters, and the quotient equals ten, or the amplitude of accommodation expressed in dioptres, or the amplitude of accommodation of an emmetropic eye with a Punctum Proximum of ten centimeters.

The range of accommodation shows the availability of the eye, and the amplitude of accommodation, the change in the index of refraction of the eye.

Hyperopes require some of their accommodation to produce distinct, distant vision. Therefore, in order to determine the amplitude of accommodation, we must either have such a glass as corrects their hyperopia, before taking their near point, or add to the near point expressed in dioptres the correction for distance. Given a case hyperopic by 5 dioptres, when the near point was 33.3 centimeters, $\frac{100}{33.3}$ equals $3 + 5$, (or the number of dioptres of hyperopia present) equals 8 dioptres or the amplitude of accommodation.

In myopia the reverse is true. Find a glass

that has a focal distance equal to the Punctum Proximum and deduct the correction for distance. A myope of four dioptres with a Punctum Proximum of 8 centimeters $\frac{100}{8}$ equals 12.5 — 4, (or the number of dioptres of myopia) equals 8.50 dioptres or the amplitude of accommodation of a myope of 4 dioptres having a Punctum Proximum of 8 centimeters. With the same ciliary muscle the Punctum Proximum is nearer in myopia than in emmetropia and nearer in emmetropia than in hyperopia. We speak of the absolute accommodation as the amount of accommodation that can be used when one eye works alone, and of the relative accommodation as the amount that can be used when both eyes act together. As we know, the elasticity of the lens substance changes with age and with it gradually decreases the possibility of accommodative changes. Accommodation is greatest at about ten years of age, at which time it represents about 14 dioptres, and approximately it may be said to decrease .3 of one dioptra each year until forty years are reached, after which each year may be said to decrease .2 of one dioptra, until at 65 years of age very little, if any, accommodation remains.

CONVERGENCE.

By convergence we maintain binocular vision when the object of fixation is brought nearer the eye than infinity. Convergence is then the rotating

inward of the eyes in a regular manner so that the visual axes may meet at any point between infinity and a few centimeters from the face. Or, convergence may be said to be the power of directing the visual axes of the two eyes to any given point, provided this point is somewhere inside of infinity. The range of convergence may be called the difference between the Punctum Remotum and the Punctum Proximum of binocular vision. The meter angle is used as the unit of measurement of convergence. When the eyes converge to an object one meter distant, we say this convergence equals one meter angle or the unit of measurement of convergence. If for 50 centimeters, the convergence equals 2 meter angles. If for 25 centimeters, the convergence equals 4 meter angles and the measurement of the meter angle is the inverse ratio of the distance as is the amplitude of accommodation in dioptres.

The exact value in work done, or the amplitude of convergence, can only be determined accurately when taken in consideration with the interpupillary distance which is constant in each given person, but not constant as between different persons. There is a co-ordination between accommodation and convergence which produces harmonious combined action, and yet they are capable of coordinate action when their equilibrium is disturbed; as will be shown by the following:

An emmetrope fixing an object one meter distant uses one dioptra of accommodation and one meter angle of convergence. Disturb their equilibrium by adding a —2.00 dioptra glass in front of the eyes, or by substituting for the emmetrope a hyperope of 2 dioptres, and 3 dioptres of accommodation are used, and only one meter angle of convergence, yet there is harmonious action of the two faculties. Again substitute a myope of one dioptra for the emmetrope and no accommodation is made, yet one meter angle of convergence acts and vision is binocular and perfect.

The maximum convergence minus the minimum of convergence equals the amplitude of convergence. The maximum of convergence equals about 9.5 meter angles. And the minimum of convergence will be seen to be equal to minus one meter angle. Subtracting the minimum from the maximum the remainder will be 10.5 meter angles or about the average amplitude of convergence. The power of convergence depends on the relative strength of the internal rectus muscles. When the eyes are adjusted for infinity the optic axes are generally a little divergent. Therefore an angle results between the optic and visual axes.

In emmetropia this angle generally equals about +4 degrees, in hyperopia about +7 degrees, in myopia about —2 degrees. The Punctum Remotum of convergence is therefore often beyond

infinity. To test the convergence when we have no instrument made for that purpose, we place prisms base outward and generally 30 degrees to 40 degrees are overcome. Prisms as you know are numbered according to the angle of the prism and produce about one-half the deviation of light that their mark indicates. If a prism is placed before one eye, it is in effect equally divided between the two. When the base line is of an average length or about 62 millimeters, a meter angle equals about 1.75 degrees of a circle and requires a 3.5 degree prism, according to the old numbering, to equal in effect, one meter angle of convergence. To diminish the convergence by one meter angle a 3.5 degree prism is placed in front of each eye, base in. Prisms are now being numbered by many manufacturers according to the deviation they produce and are marked with a *d* following the number designating their strength, as $2°d$, meaning that a $2°$ deviation is produced by the prism.

If you will call the base line the distance between the centers of rotation of the two eyes, which for practical purposes may be called the pupillary distance, and erect a perpendicular to this line at its midpoint, any object situated on this perpendicular line demands equal convergence of both eyes when fixed. Suppose a case with an average pupillary distance or 62 m. m. to be fixing an object 1000 millimeters (1 meter) away. One-half the pu-

pillary distance, or 31, divided by the distance of the object of fixation in millimeters being in this case 1000 = .031 which is the sine of 1 meter angle. The sine and the arc for these angles are practically equal. .031 is then the sine of the angle formed by 1 meter angle of convergence used by a person having a pupillary distance of 62 millimeters (or about 2.48 of an inch), which equals 1° 46′+. If an object is ½ of a meter distant and is fixed by the same person .062 is the sine of the angle of convergence.

The value of the meter angles in degrees is approximately obtained by multiplying 1° 46′ by the number of meter angles. The deviation of the meter angle is measured on the sine.

A prism dioptre is a prism which shall deflect light 1 c. m. at 1 m. distance, or one hundredth part of the radius measured on the tangent.

Dennett's Centrad is a prism that will produce a hundredth part of the deviation of a prism whose length equals the radius of its curvature. This arc equals 57.295°. This will give uniform deviation, ten centrads having ten times the deviation of one centrad.

Should either of these ideas become universal, as Mr. Hardy urges, when a lens is decentered one centimeter, the prismatic deviation of the lens will be equal to as many prism dioptres as the number of dioptres of the lens.

When the eye fixes any object and an image is formed on the macula lutea, a line drawn from the macula to the object of fixation is called the line of visual axis.

The optical axis of the eye is a line drawn exactly through the center of the cornea and lens to the posterior boundary of the eye. Now if the posterior end of this optical axis falls in the center of the macula, the optical axis and the line of visual axis and the line of fixation (which is an imaginary line drawn from the center of rotation of the eye to the object fixed) coincide.

With the hyperope and, generally, with the emmetrope the optical axis passes to the inner side of the macula, and either the line of visual axis or the line of fixation forms an angle with the optical axis. The angle formed by the latter, forms the angle gamma, while the angle formed by the visual axis with the optical axis is often considered as the angle gamma, being easier to determine clinically. A line intersecting the cornea at right angles to its summit, continued back, may form an angle with the line of visual axis and is known as the angle alpha. The angle gamma is called + when it lies on the nasal side of the optical axis and — when on the temporal side.

In high myopia the angle gamma is often — and an apparent convergent squint is produced when fixing a near object. Likewise when

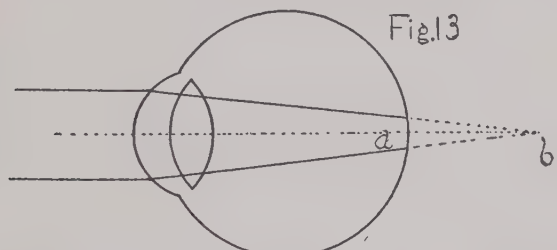
the angle gamma is + there is an apparent divergent squint and before operating, for strabismus, the determination of the angle gamma should be made and allowed for in the correction given.

CHAPTER IV.

Hyperopia.

Hyperopia is that refractive condition of the eye in which parallel rays of light falling on the cornea come to a focus behind the retina. The retina then is situated between the lens and the posterior principal focus of the eye, and only when rays are convergent before they fall on the cornea can they be focused on the retina without the aid of accommodation. In hyperopia, when parallel rays fall on the cornea, they reach the retina and are cut off by it before a focus is obtained.

Fig. 13



Therefore it is evident that the hyperope, even when looking at distinct objects, requires the help of accommodation to produce a clear image on the retina. In order that rays of light coming from a distant object should be convergent when they fall

on the cornea they must start back of infinity, or at a point far enough away so that, if parallel lines were produced from it, and were on their way to infinity, they would begin to converge. Hence the Punctum Remotum of the hyperope is beyond infinity.

In old age the cornea flattens and the eye becomes hyperopic so that often an emmetrope at 30 requires a correction for distance when reaching 70 years of age. Nothing can be plainer than that the more hyperopic the eye, the more convergent must be the rays of light when falling on the cornea, in order to meet when they reach the retina.

Hyperopia may result from either the axis of the eye being relatively too short or the refraction of the eye being relatively too weak; the former is generally the case.

The amount of hyperopia is known by the distance of the far point from the eye. The Punctum Remotum of a hyperope may be expressed by a minus quantity, or the distance between the posterior principal focus of the eye and the retina, as in Fig. 13. The distance from *a* to *b* which we will suppose to be 25 centimeters expressed as a minus quantity is the far point of this eye four dioptres hyperopic.

The correction in this case would require a lens whose focal distance is 25 centimeters which we know is ($\frac{100}{25}$) 4.00 dioptres.

Therefore the correction would be a +4.00 dioptra lens which would give clear vision to a hyperope whose Punctum Remotum equals a —25 centimeters. Without this correction, clear images are only obtained at the expense of 4.00 dioptres of accommodation.

Hyperopia is called Manifest where it is not masked by the accommodation and accepts of correction without a mydriatic, in contradistinction to Latent Hyperopia which refers to the hyperopia which is hidden by the action of the ciliary muscle. The Hyperopia Total of some writers refers of course to the Hyperopia Manifest plus the Hyperopia Latent. To determine the total hyperopia, the action of the ciliary muscle must be suspended by the thorough use of a mydriatic. In youth, while the accommodation is very strong, less of the hyperopia is manifest, but as age gradually advances, more and more of it becomes so, until after 50 years at latest, practically all becomes manifest.

This, of course, should be remembered in determining the per cent. of the correction to be prescribed, that is, the younger the person, the less of his correction to be given, other things being equal, or, in other words, persons under 18 years are seldom given a full correction for hyperopia, unless the convergence is evidently overstimulated. While at 40 years the total correction, unless very great, would be at once extended. However, in young

persons, where the lens is to be worn for near work only, a full correction is often accepted immediately. When a determination of hyperopia with insufficiency of the internal recti is made, both or neither should be corrected. To correct the hyperopia and leave the insufficiency uncorrected would be to lessen the stimulus aiding the already faltering convergence.

When a person has a large amount of hyperopia (three to ten dioptres), it should not all be given at once, but at first a little more than the eye will accept with clear distinct vision, gradually increased until the desired amount is accepted. The desirable ultimatum depends on the amount and effect of the ametropia. From this standpoint hyperopia may be classified in three divisions.

To the first class belong people with a small amount of hyperopia .50 to 1.50 dioptres, who have little or no trouble unless continued near work is indulged in. For these a full correction for reading, or a partial correction for distance, if required, may be given. These are called by some Facultative Hyperopes.

To the second class belong persons suffering from so great a degree of hyperopia as to have produced insufficiency of the external rectus muscles or even convergent strabismus. For this class, often called Relative Hyperopes, a full correction is desirable and generally imperative.

To the third class belong those persons afflicted with a very great degree of hyperopia where the visual acuity is extremely low, and where the object is drawn up close to the eye to produce a large retinal image. These people are often mistaken for myopes, and are called by some Absolute Hyperopes.

Visual acuity is so affected that the usual test is quite unsatisfactory, little difference being noted by a change of two or three dioptres in the test lens. In these cases the lens should be given which gives the best general vision to the patient, and by other instruments of precision the total error recorded, and the strength of the lenses increased as it will be accepted, within the limit of total correction. A person who has normal visual acuity and yet presents himself for examination is suspected of hyperopia, especially if the usual symptoms are complained of, that is, headache and pain after near work, feeling of sand in thes eye and congestion of bulbar conjunctiva. In using the subjective method for determining hyperopia, the first step is to take the visual acuity of each eye separately. This is done by placing the patient 20 feet from Snellen's test card, and requesting him to read the line marked 20 feet. This is generally read in simple hyperopia and is recorded on a card as follows:

Optica Dextra V. A. = $\frac{20}{20}$.

Optica Sinistra V. A. = $\frac{20}{20}$.

In this fraction the numerator expresses the number of feet the patient is from the card and the denominator is the number of feet at which the line the patient reads should be read. If a line that should be read at 40 feet is the best that the patient can read when 20 feet from the card the record would show:

Optica Dextra V. A. = $\frac{20}{40}$.
Optica Sinistra V. A. = $\frac{20}{40}$.

After this record has been carefully made the eyes are put under the influence of a mydriatic. Various are the opinious of the proper one to use, but it is generally agreed, except in cases of spasm, that eight instillations (of a solution containing one grain, to the dram, of both Cocaine Hydrochlorate and Homatropine Hydrobromate) made five minutes apart with a ten minute rest, after the last application, is entirely sufficient to completely suspend the accommodation.

Gelatine discs of the same ingredients are often used having the advantage of self-preservation which is much wanting in the solution. The solution is far preferable when it can be used, and should be dropped over the upper margin of the cornea while directing the patient to look down. The annoyance of the bitter taste in the throat, when using the solution, is much lessened by holding the finger tip over the punctæ a short time after each application. After this procedure the patient

is again placed in the chair 20 feet from the test card and the reading of each eye separately taken again. This is recorded as before and shows the vision without the aid of accommodation. The trial frame is now placed on the face with an opaque disc over the left eye and the total hyperopia of the right eye determined by beginning with the weakest plus glass and increasing until the *strongest plus glass is found with which the best or normal visual acuity is obtained.*

This is the measure of hyperopia. The amount is recorded and the opaque discs placed over the right eye and the procedure repeated with the left eye. After the measure of hyperopia has been ascertained in both eyes the record presents this appearance:

John Doe aet. 20 years.

Optica Dextra V. A. = $\frac{20}{20}$, after the V. A. = $\frac{20}{40}$ with +2.50 D.-V. A. = $\frac{20}{20}$.

Optica Sinistra V. A. = $\frac{20}{20}$, mydriatic V. A. = $\frac{20}{30}$ with + 1.75 D.-V. A. = $\frac{20}{20}$.

In hyperopia when prescribing lenses where one eye presents by far a greater degree of hyperopia than the other, as Optica Dextra + 3.00 dioptres; Optica Sinistra + 10.00 dioptres; the less ametropic eye is given its correction and the more ametropic eye is given but slightly more than the good eye. Should the full 10.00 dioptres be given to the left eye, the retinal image would be so differ-

ent in size as to produce disgust and disuse of the lenses. This is equally true in myopia and more practical as the myopic eye is more sensitive.

The strongest plus glass is the correction because there may not be full mydriasis. And the action of accommodation assisting a + 2.00 dioptra glass would correct 3.00 dioptres of hyperopia, if 1.00 dioptra of accommodation were available.

In using instillations of sulphate of atropine where the instillations are repeated daily for some time, as in cases of spasm, many advise that ½ to 1.00 dioptra be subtracted from the total finding. I cannot appreciate this advice myself, having often eventually given the full correction taken under atropine sulphate, which was happily accepted. When the hyperopia is considerable, three dioptres or more, it is always best to begin with a weak glass that corrects a little more than the manifest hyperopia, which glass is changed and increased in strength as soon as clear distant vision is obtained until the total amount to be worn is accepted.

The glass that corrects must be of such a strength that it will render parallel rays of light falling on its surface convergent enough to meet at the Punctum Remotum of the hyperopic eye, no matter at what distance the glass is placed in front of the eye. The farther from the eye the glass is placed the greater must be the focal distance of the glass (and hence the weaker the glass), to make

parallel rays of light falling on the glass meet exactly at the Punctum Remotum of the hyperopic eye. An eye with a Punctum Remotum expressed by a — 100 millimeters requires a + 10.00 D in contact with the cornea to correct the ametropia. Place the plus glass 13 millimeters in front of the eye, and so situated, the correcting glass must have a focal distance of 113 millimeters, which we know is about a nine dioptra lens. *Hence the effect of a plus glass is increased as it is moved farther from the eye.* One exception to this rule must be noted. When the object of fixation is less than twice the focal distance of the glass from the eye, the effect of the plus glass decreases as the glass recedes.

A person who obtains a clear image of a distant object by moving the lenses away from the eyes should have a stronger glass to wear for distance. A person who reads better when the lenses are farther from the eyes, should have weaker lenses for reading, provided the reading is done within twice the focal distance of the glass worn. The application of this rule often proves of benefit in advising persons, at a distance, about lenses, of which they write.

It exceptionally occurs that a hyperope of extreme degree, as 8.00 dioptres, obtains best visual acuity with a fraction of his total correction, say in the case cited + 3.00 dioptres; this is because the

visual acuity is lowered by the existing hyperopia; the eye becoming somewhat amblyopic. In correcting these cases the most acceptable glass is given and the total hyperopia determined by the skiascope and ophthalmoscope and recorded. From time to time a more full correction should be offered as often the visual acuity improves after wearing a correcting lens.

In prescribing correcting lenses for a hyperope it should be remembered that the greatest visual acuity is obtained when the focus of rays falls exactly on the layer of rods and cones. Rays from objects four to six meters distant are not exactly parallel, though often considered so. From this fact it follows that the strongest plus glass very slightly over corrects the hyperope when exactly parallel rays are considered. Hence it is that the idea of subtracting $\frac{1}{4}$ of 1 dioptre from the total correction becomes worthy of consideration, provided the test was made with the test card not over 6 meters distant. After a hyperope is corrected and still under the mydriatic he should read print held the focal distance of any glass which is added to the correction. If the correcting lens is a + 2.00 D. and a + 5.00 is added, he should read print at 20 c. m. and if he reads fine print farther than this distance, while both lenses are on, he is not fully corrected. If much nearer, he is over corrected. When under the mydriatic, the hyperopia

may be determined, when dealing with young or illiterate people, by noting with what glass they can count small dots placed 25 centimeters in front of the cornea. This as we know should demand a + 4.00 D. lens, and if it requires a + 7.00 there exists 3.00 D. of hyperopia. In testing for hyperopia without a mydriatic, as is often done between 35 and 50 years of age, it is of advantage to begin with a strong lens and run down the scale. Some advise that both eyes be tested at once to avoid exercise of the accommodative power, but this will not prove generally satisfactory, as in many people the two eyes vary much in the degree of ametropia.

After the use of sulphate of atropine the correction desired is often given at once and ordered worn as the effect of the drug leaves the eye, and the changing and strengthening of the lenses thus avoided. In cases of high degrees of hyperopia and spasm, reporting at the clinic, after the homatropine solution had been used and the hyperopia determined, the patient has been treated with atropine sulphate until the next clinic day, but never so far as observed has the sulphate revealed more hyperopia than was evinced after the homatropine solution was used.

CHAPTER V.

Myopia.

Myopia is that refractive condition of the eye in which the parallel rays of light falling on the cornea come to a focus before they reach the retina. It is readily seen that this may result from too strong a refractive media or from an increase of distance between the retina and cornea. When rays of light entering the eye become divergent enough to require this extra amount of refraction (possessed by the myopic eye), to produce a clear image on the retina, then is the visual image clear. This clearing of the image is accomplished in two ways. By bringing the object near enough to produce a sufficient divergence of rays emanating from the object to atone for the extra refraction of the eye, or by the use of proper concave glasses. The former is the method made use of by the unskilled and constitutes nature's myopic panacea.

Myopia is always present when the image is formed in front of the retina, if the accommodation be at rest.

The cornea, far from being more convex in myopia, is generally less so, and the index of refraction of the lens in the myopic eye does not mater-

ially differ from the lens in the emmetropic eye. Myopia, as a matter of fact, therefore, is generally due to elongation of the visual axis of the eye, and hence the myope presents, relative to the position of the retina, an excess of refraction. When myopia is not so great as to bring the far point within the place where work is held, it does not present a formidable trouble, unless progressive. It allows near work with less exertion of the accommodation and is often called the anomaly of culture, especially as it is found in more highly educated classes and only in the human eye, hyperopia being the rule with the lower animals. An eye myopic by ½ to 3.00 dioptres is often a much better eye than an eye hyperopic in the same degree, and yet the hyperope can use accommodation for far and near work and attain good vision for both distances, while there is no reverse accommodation that the myope can use for his distant work. The myope sees better in advanced age on account of presbyopia, also because the pupil becomes smaller and this lessens the size of the diffusion circles formed on the retina. The use of the stenopaic slip helps the myopes vision because it cuts off part of the rays of light. One trouble often presents itself in medium myopia—disproportionate amount of convergence and accommodation used. The convergence demanded to sustain binocular vision in the myope is practically the same at any given dis-

tance as in the emmetrope. Physiological co-ordination of these two functions exists in emmetropia, and accommodation always stimulates convergence, as we have seen before; hence it is not wonderful if the myope experiences great difficulty in maintaining convergence as he uses little or no accommodation. As the hyperope produces too much convergence by the abnormally large amount of accommodation used, so the myope produces too little convergence by the abnormally small amount of accommodation used. From this anomaly divergence often results, and it affords the most frequent cause of asthenopia in typical and medium myopia. When once the effort to sustain binocular vision has been given up, the eye persists in its wandering, the retinal image is suppressed and the result is divergent strabismus with amblyopia exanopsia of the diverging eye, and the effort of accommodation and convergence which informs the emmetrope of the proximity of the object is gone. Insufficiency of the internal recti is most common in myopes, and when the myope does near work he is quickly fatigued, and suffers from pain in the head and even dizziness which gradually increase in intensity, provided this insufficiency exists, until the near work is discontinued or the proper correction given.

This, then, is the trouble dependent on me-

dium myopia. Visual troubles are much more pronounced in high degrees of myopia.

Binocular vision for near work becomes impossible, muscae volitantes form a source of great annoyance and monocular diplopia appears with hyperæsthesia of the retina, and hemorrhagic scotomata. The eye is elongated, large, voluminous, with an enormous antero-posterior diameter.

The movements of the eyeball are limited mechanically because it loses its spherical shape except at its anterior and posterior aspect; and it requires much more force to perform its excursion or to converge. The field of possible fixation is very limited. The muscles lose their elasticity from distension and the ophthalmoscope shows, in many of these cases, an unusual crescent, and characteristic choroidal changes.

The term malignant myopia is applied to a myopia when it is persistently progressive. Malignant myopia is accompanied with many intra-ocular changes and fraught with the most serious dangers.

It is somewhat hard to diagnose in its incipiency; generally the hyperæmia of the retina, the red disc, rapid increase of the myopia, coupled perchance with hereditary history will enable us to avoid error in diagnosis. Scintillation, photopsia, and metamorphopsia, which are due to the retinal hyperæmia also act as pilot fish and give warning

of the progressive character of the disease. Irregular pigmentation and the crescent can soon be observed at the external edge of the papilla and the vessels seem to enter the disc nearer the temporal side of the nerve. The disc even becomes indistinct and later the hyperæmic inflammation subsides and leaves an atrophic condition of nerve and retina, the crescent is generally increased, the exudate resorbs and leaves the white sclera in patches showing through. The posterior region becomes ectasic because the region of the lamina cribrosa offers the least resistance and posterior staphyloma follows. The whole visual axis of the eye elongates, the choroid continues chronically inflamed, the vitreous liquefies and carries about in its substance parts of the retinal and chorodial coats, and, as if to draw a curtain on the deplorable scene, detachment of the retina often ends the functional life of the organ.

The chief causes of myopia are first heredity; second, a long continued over amount of near work; third, a poor position in which the work is done; fourth, everything that tends to impair the general health.

Of the first, many attribute a hereditary weakness of the sclerotic coat as a great factor, especially in malignant myopia, and all admit that an over amount of near work, between the years of 4 and 18 is very productive of the malady. Young

children who become so intent over their kindergarten pictures and work, their books and toys, as to continually work at them at a distance of 10 or 12 centimeters produce more myopia than is produced in all other ways. In reading, the head should be kept erect, as bending the neck shuts off the free return of blood from the head, and congests the choroidal vessels. This bent position is the one naturally assumed, however, by the child elated with a new picture book or kindergarten structure. The full development of the eye is reached between the ages of 12 and 18 years, and if the child is carefully guided past this period one need have little fear of myopia.

The treatment of myopia will be considered under four heads.

First. Prophylactic—Which consists in insisting on work being done at a proper distance, and in proper amount only; in seeing that the position is correct; in having side or rear illumination of equal intensity, and in building up and maintaining the general health. One instance only will suffice to show the extreme benefit of this part of the treatment. A child, age 4 years—mother myopic by four dioptres—child had taken greatly to picture papers, kindergarten work and toys. After one year's work of this kind child was pale, delicate, with capricious appetite, and skiascopy showed a myopia of 1.00 dioptre. All books and toys

were discontinued, child turned out doors to play, and whenever looking at near work (which she persisted in holding about 12 centimeters distant) was instantly treated to a pair of 1.50 dioptres plus lenses. The result was that one year and four months later the eyes were normal, the body having caught up to them. This then should be our aim in treating cases of myopia beginning in young children.

Second. Age—Static refraction diminishes with age and if slight, will be entirely rectified in time. Unfortunately this self-remedy is not applied until 50, and reaches but 2.50 dioptres at about 80 years of age.

Third. The operative method—The removal of the crystalline lens will relieve quite a degree of myopia. Unfortunately, however, the lens in a normal state is too seldom successfully extracted to warrant the procedure. When opacity and age favor absorption or if the lens is ripe enough to allow extraction, it may, in severe cases, be admissible.

Pseudo-myopia due to the spasm of accommodation is of course relieved by the instillation of atropine or some other mydriatic, which must often be continued for a considerable length of time.

Fourth. The optical treatment—Since it is impossible to cure myopia or even diminish it, we must content ourselves with adjusting concave glasses that will give clear vision and yet allow

near work. Having found the weakest glass that gives the best or normal visual acuity (which is the measure of the myopia), if it be two dioptres or under, it will generally suffice to give a distance glass only, as near work within fifty centimetres, can be carried on easily without the aid of a lens. If the finding be over two and under four dioptres and the accommodation be very good, the one glass will answer for distance and reading both, provided the internal rectus muscles have previously been somewhat insufficient in performing their work of convergence. This having been the case the myope complains of having experienced trouble in reading without correction. On the other hand if the myopia equals four dioptres and the accommodation be poor, this person will experience great difficulty in reading through the correcting glass, if it be even possible. It is therefore important in treating myopia to determine the amplitude of accommodation. This will be done in the following manner. Take the near point in millimeters (which we will suppose to be 111 millimeters), divide the number of millimeters in a meter or 1,000 by the near point expressed in millimeters, or 111, and the quotient will equal 9. Subtract the degree of myopia in dioptres, or in this case 4.00, and you have the amplitude of accommodation which equals 5 dioptres. Now you know from the chapter on accommodation that 5 dioptres of accom-

modation fill all requirements made on this myope in reading through the correction. Again you take a myope of 4 dioptres, who shows a near point of 200 millimeters. (1,000 ÷ 200 = 5), — 4 = 1.00 dioptre, amplitude of accommodation. If this person myopic by 4.00 dioptres were to be presented with a minus 4 dioptre glass for near work, possessing only 1.00 dioptre amplitude of accommodation, the result would hardly be gratifying, as one cannot work with ease when over three-fourths of their accommodation is constantly exerted.

Now, in the first instance, having 5 dioptres of accommodation at command, after the correction of the myopia, if the glass is not used for reading, asthenopia will likely follow continued near work, as a result of the want of co-ordination between convergence and accommodation. In the case last mentioned, asthenopia will also result without or with the minus four dioptre glass given as a correction, as there is practically no accommotion. Then, in the case lacking the accommodation, we have yet to relieve the asthenopia due to the effort of convergence. This can be done in two ways. First, by carrying the point of fixation further away, by such a part of the correction as the accommodation permits of, coupled with prisms to still more moderate the demand on the internal recti; or the prisms may be used alone.

Suppose a case demands 10 meter angles of convergence to do near work and has 4 dioptres of myopia, one and one-half dioptres amplitude of accommodation and eight meter angles of convergence. One dioptre of correction will be accepted and will remove the point of fixation by one meter angle and the myope will work at one-third instead of one-fourth of a meter. This removes the near point so expressed one meter angle and the demand for the still remaining meter angle deficiency, is supplied by three and one-half degree prisms base in. With this correction the patient works at over 25 centimetres with ease, and, relieved of this muscular asthenopia, can pursue his near work any reasonable length of time.

A myope of 2.00 dioptres should do work at 50 centimeters without trouble, and this distance includes the performance of the practical duties of life of the carpenter, the blacksmith, the piano player and most others. If this work is impossible in such a myope it is because of spasm of accommodation, which is to be treated with atropine. If the work be nearer than 50 centimeters, say 33 centimetres, there will be found in nearly all cases, at least one dioptre of accommodation present which will enable him to do such work. If, however, the patient be old or the accommodation nothing, one dioptre plus glass would be indicated for this work. In each case compatibil-

ity of accommodation and convergence must be remembered and consideration given whenever demanded. While three-fourths of the accommodation may continually be used, only one-third of the convergent power is available for prolonged labor. Hence we should determine the amplitude of convergence and compare it with the amount required by the distance of the work to be followed.

Often in low degrees of myopia, choice must be made between a minus glass and a prism for near work. In high degrees of myopia the diminishing influence of the glass places it open to much criticism for near work, especially among laborers, as so many dioptres are required to gain so few centimeters in distance. A myope of 20 dioptres must give 8 dioptres for the 3 centimeters increase in distance, and on this account prisms are more often prescribed. Again the prisms are heavy and often rejected, and this pushes us on to attempt the surgical help to convergence, or the partial or complete tenotomy of one of the external rectus muscles. This procedure is practical and is destined to hold a very much higher place in the treatment of myopia coupled with insufficiency of the internal recti. Complete tenotomy of one external rectus muscle seldom over corrects the myope having over 20° if insufficiency of the interni.

The lorgnette is used for the occasional help of myopes who do not accept a constant correction,

and some have even attempted to give the myope a large inverted image by placing a strong plus glass at a little distance from the eye, which would throw the inverted image of the landscape just in front of the face. This would seem impracticable however. The diminishing effect of a concave glass is increased as it is removed from the eye. Hence it is desirable to place the glass as near as possible to the myopic eye. The concave glass always increases the range of accommodation. In extending the correction to myopes of high degree, they should be given a partial correction, which is gradually increased until the desired lens is worn.

Should a full correction be at once given in cases of 6.00 to 12.00 dioptres of myopia, the patient would often be unable to continue wearing the lenses on account of the sudden change produced in the focus of the rays of light, dizziness and headache resulting.

CHAPTER VI.

Astigmatism.

In the preceding cases rays of light coming from a given point fell on the cornea and were brought to a common focus, the light being equally refracted in all meridians of the refracting surface. We have now to consider that refractive condition in which different meridians refract light in different degrees.

ASTIGMATISM.

From what has been already studied on refraction it is readily seen that astigmatism may be either myopic or hyperopic. When in myopic astigmatism one meridian is normal and one myopic it is called Simple Myopic Astigmatism. When both are myopic and one is in excess of the other, it is called Compound Myopic Astigmatism. When one meridian is myopic and the other hyperopic it is termed Mixed Astigmatism.

When in hyperopic astigmatism one meridian is normal and the other hyperopic it is called Simple Hyperopic Astigmatism. When both are hyperopic and one is hyperopic in excess of the other it is termed Compound Hyperopic Astigmatism.

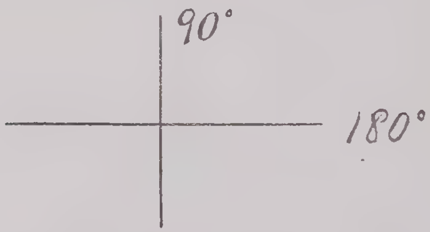
Astigmatism is regular when the refraction is equal in the two radii of any given meridian, irregular when the refraction is not the same in the two radii of any given meridian. In regular astigmatism the meridians of greatest and least curvature are always at right angles to each other. Of the two meridians the one of greatest curvature, having the greatest refraction—the one with the shorter focal length—is as a *rule* vertical, and the meridian of least refraction, therefore, horizontal. The vertical meridian is the meridians of 90°. The horizontal meridian is the meridian of 180°. *This is called astigmatism with the rule.*

When the greatest curvature of the astigmatism is at 180°, the astigmatism is said to be against the rule. When the meridians of greatest and least curvature do not fall on either axis, 90° or 180°, astigmatism is said to be of irregular axes. This must not be confounded with irregular astigmatism. Nearly every eye has some corneal astigmatism. The cause of this may be found in the position of the lids, tending by their attachment to preserve a greater curvature of the cornea at 90°, also by the oblique position of the refracting surfaces to the visual line. Other causes that produce astigmatism are, progressive myopia, corneal scars, operations in the cornea, as cataract operation or iridectomy.

The vision is not simply indistinct as in hyper-

opia and myopia, but presents irregular images due to the diffusion circles formed on the retina in one or both meridians. Let us take the case of Simple Hyperopic Astigmatism with the rule, and the cornea over the meridian of 90 degrees, that is over the vertical meridian, has the greatest curvature and focuses light on the retina. At 180° or over the horizontal meridian there is less curvature, less refractive power, and the focus of this meridian is behind the retina.

At first sight one would say, that when looking at the cross-lines,

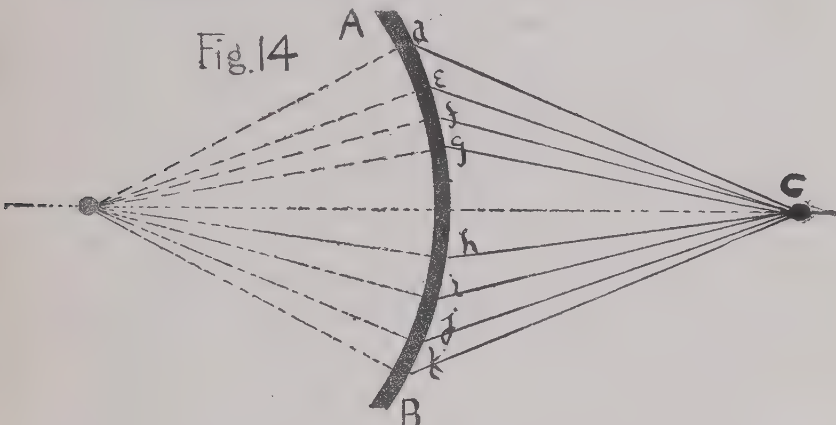


the 90° line would be plainer and 180° line dimmer. Now carefully consider the line at 90°. It gives off many divergent planes of light to the right and left of the central plane, all of which are plainly dealt with by the 180° meridian. So the 180 degree meridian being of too small a refractive index in Simple Hyperopic Astigmatism, the 90 degree line will be not distinct but blurred, and from the same reasoning the 180° line will be distinct, as the 90° plane is correctly adapted for the retina.

Hence it is that the line seen plainly on the astigmatic chart is at right angles to the correct or most nearly correct meridian.

Diagram to show that the horizontal line depends on the emmetropia of the vertical meridian for a distinct image:

Fig. 14



Let *A. B.* represent the meridian of 90° in the eye with Simple Hyperopic Astigmatism. This meridian is therefore correctly adapted to the position of the retina. Let *c* be the end of a horizontal line, *c d*, *c e*, *c f*, *c g*, *c h*, *c i*, *c j* and *c k* represent rays or planes of light given off from the horizontal line, which are evidently dealt with by the cornea *A. B.* at axis 90.

The degree of astigmatism is expressed by the difference between the meridian of greatest and least curvature.

Whenever normal visual acuity cannot be attained with spheres, we must undertake to determine the astigmatism. This is most easily accomplished by placing the stenopaic slit over the eye in either principal meridian and finding the sphere that most nearly or quite gives normal visual acuity. Then removing the lens turn the stenopaic slit at right angles to the meridian first used and find the sphere to correct this meridian, from which two results a deduction can easily be made. To determine at what meridian to place the stenopaic slit, the astigmatic chart is brought into use and the slit may be placed first at right angles to the plainer lines seen on the astigmatic chart, which is the meridian of emmetropia or the least ametropia.

From the amount of ametropia in each meridian the determination of the difference in the two meridians is easily made, and should be corrected by use of a cylinder added to the sphere which corrects the meridian of least ametropia. In supplying this cylinder it must be remembered that a cylinder refracts light only with the meridian at right angles to its axis, and when a cylinder is prescribed to correct the meridian of 180° (as in Simple Hyperopic Astigmatism) it is put on at axis 90°.

In Compound Hyperopic Astigmatism with the rule the sphere is used to bring up the meridian of 90° to the retina, and also to bring the image

formed by the meridian of greater error (or 180°) part way up to the retina. The cylinder is then added at axis 90° to finish the correction of the 180° meridian, and the prescription reads, plus 1.00 sphere combined with plus 1.00 cylinder axis 90°, and this corrects the Compound Hyperopic Astigmatism with the rule.

MIXED ASTIGMATISM.

In using the stenopaic slit when one meridian is corrected by a minus sphere and the other by a plus sphere, mixed astigmatism is present and to combine this in one lens a Stokes' lens is produced.

CASE.

Stenopaic slit at 180° plus 1.00 sphere obtains normal visual acuity.

Stenopaic slit at 90° minus 1.00 sphere obtains normal visual acuity.

The Stokes' lens correcting would be plus 1.00 cylinder axis 90° combined with minus 1.00 cylinder axis 180°, (remembering that a cylinder refracts light only at right angles to its axis). This Stokes' lens may be reduced to a sphero-cylinder, using a + 1.00 sphere which corrects the meridian of 90° and renders the meridian of 180°, one dioptre more myopic then demanding a minus 2.00 dioptre cylinder axis 180° (to correct the 1.00 dioptre of myopia of the eye and the one additional dioptre of myopia produced by the plus 1.00

sphere), the correction would read, plus 1.00 sphere combined with minus 2.00 dioptre cylinder axis 180°.

After the student has experimented in the correction of astigmatism with the stenopaic slit it is desirable to determine it also by the use of the sphere and cylinder. The sphere is increased as long as visual acuity is bettered, the cylinders being used when the sphere fails. In a case of hyperopic astigmatism after the strongest plus glass is used that betters visual acuity a plus cylinder is added (first at axis 90°) which is strengthened if of benefit, until normal visual acuity is reached. If the cylinder at axis 90° does not prove of benefit the axis of the cylinder is slowly turned until it is rotated through an arc of 180°, as the astigmatism may be of irregular axes or against the rule. When this is not of benefit at any axis a minus cylinder is placed at axis 180° over the sphere, because the plus sphere may already over correct the meridian of least ametropia. This cylinder is also rotated that it may rest on every possible axis and when this combination proves best it is reduced to a plus sphere and a plus cylinder having a different axis but producing the same optical effect (+ 3.00 sph. $\frown$ — 1.00 cyl. axis 180° = + 2.00 sph. $\frown$ + 1.00 cyl. axis 90°). In determining myopic astigmatism the same procedure is observed with minus spheres first combined with minus cylinders. It is also

expedient to notice the axis of greatest and least ametropia before starting to determine astigmatism by the use of spheres and cylinders. In determining visual acuity during refraction the attention of the patient should be directed to some one particular letter and this letter should be one of the more complicated in structure.

In irregular astigmatism visual acuity is poor, and often double images are seen by one or both eyes, and images appear distorted.

Lenticular astigmatism, when irregular, presents a deplorable picture, especially when myopic. No correction is accepted; images are reproduced in various parts of the field of vision, and often to read large type part of each eye must be excluded when receiving the image. This exclusion of part of the pupil may shut off some of the many images formed from the one object. Such cases of ametropia are, however, happily very rare.

Put a weak cylinder before the eye and the astigmatism produced is corrected and often over-corrected by the ciliary muscles. Again, after the instillation of atropine the meridian of greatest curvature often changes, showing that the corneal astigmatism had been over-corrected by the irregular contraction of the ciliary muscle. Hence astigmatism, if uncorrected, will seem to increase as accommodation fails, because it will not be so fully corrected by the action of accommodation.

CHAPTER VII.

Presbyopia.

THE VISION OF OLD AGE.

Presbyopia is that condition of the eye produced by age, in which the accommodation, and the vision at the punctum proximum is diminished. A person is called presbyopic when the accommodation is affected to such an extent that the punctum proximum recedes beyond 22 centimeters, or in other words, when the dynamic refraction at its utmost does not exceed 4.50 dioptres. This occurs at about 40 years of age in the emmetrope, who corrects the grievance for three or four years by moving the object of fixation a little farther away. The time arrives, however, when the farther removal of the object renders the visual acuity so poor, that common print cannot readily be seen and at this point the patient applies for help, or at about the 44th year.

The hyperope becomes presbyopic before the emmetrope, in proportion to his hyperopia. Below, is given a table denoting the amount of available accommodation or the dynamic refraction that it is

possible to use at the different ages after 40 years:

40 years	4.50 dioptres
45 years	3.50 dioptres
50 years	2.50 dioptres
55 years	1.75 dioptres
60 years	1.00 dioptres
65 years	.75 dioptres
70 years	.25 dioptres

To determine the age at which a hyperope will become presbyopic, it is only necessary to add to the 4.50 dioptres of dynamic refraction at 40 years, the amount of hyperopia existing and comparing this sum with the table above. A hyperopia of 2.50 dioptres plus 4.50 equals 7.00 dioptres or the dynamic refraction at 30 years of age. Hence the hyperope of 2.50 dioptres is at the presbyopic verge at 30 years. A few people possess a dynamic refraction stronger than the normal, preferably hyperopes, with whom the beginning of presbyopia will be relatively later. With the myope, the static refraction being stronger, it is evident that presbyopia will appear later, if indeed at all.

An emmetrope, as we have seen, will become presbyopic at 40 years of age. In order to determine the age at which the myope will become presbyopic, the amount of myopia (which is the increase of static refraction) must be added to the dynamic refraction remaining at any given age.

When this sum equals 4.50 dioptres the myope is at the entrance of presbyopia.

A myope of 4.00 dioptres at 40 years has therefore (if his dynamic refraction is normal), a combined available amount over the normal static refraction of 8.50 dioptres, and at 65 when his dynamic refraction equals plus .75 dioptres his extra amount of static refraction added to this, leaves him plus 4.50 dioptres and he is about to enter the presbyopic field; while the myope of 7.00 dioptres will become presbyopic after 80 years. Many claim that hyperopes generally have more than normal dynamic refraction and also that myopes often have somewhat less than normal dynamic refraction, hence the fitting of presbyopia by rule would lead to serious error. Again, a hyperope of any amount, if corrected, will be dispensed from presbyopia until forty.

From the phenomena produced by presbyopic changes the myope receives the credit of receiving second sight as he gets sufficiently presbyopic to overcome his excess of static refraction. The correction given the presbyope will depend on the amount of presbyopia and the work for which the glasses are intended. In testing for presbyopia (after the correction for distance has been given in both eyes, if required) they should both be tested at once by using lenses of the same denomination in each change, as the amount of accommodation

used must be the same in every emmetropic eye (with unimpaired accommodation) in fixing a certain point. In each case the work to be done must be considered and the near point brought a little nearer than the working distance.

If a person requires a plus 2.00 dioptre lens to bring his near point to 12 inches, and is a piano-player, it is evident that dissatisfaction will result if this lens is given, as his work is done much farther away than is his near point placed by the used of a +2.00 dioptre lens. The correction must, therefore, be according to the use intended, as unhappily no means of accommodation is obtainable in glass. It is well to remember that tall people generally hold their reading and work farther from the eye than do small people.

In testing for presbyopia a hand test card is used which is brought to any desired proximity. After testing for presbyopia and making a determination, it must be borne in mind that the eye will accept a stronger glass than is necessary, which glass would prevent the healthful exercise of the remaining part of accommodation when near work is done. The *measure of presbyopia is the weakest plus glass that brings the near point to the desired location.*

When a myope begins to be presbyopic the correction for reading that has been used must be gradually decreased, (which equals in emmetropia

the adding of a plus glass) as the testing indicates. If a cylinder is worn it must be left on, or ground in with the plus glass, when such a glass is demanded, until way along toward 70 years of age, when the flattening of the cornea through the 90 degree meridian, corrects the astigmatism, if of low degree, and with the rule.

It will be apparent from following the cycle of changes that go on as the person with myopia or myopic astigmatism becomes presbyopic, that the determination of the glass required for near work will be a source of great annoyance, both to the physician and patient. Neither, will the result in all cases be fortunate.

CHAPTER VIII.

Skiascopy.

BY C. B. BLISS, M. D., ASSISTANT TO THE PROFESSOR OF OPHTHALMOLOGY AND OTOLOGY.

As a means of supplementing the subjective determination of errors of refraction, skiascopy holds a prominent position, and is steadily growing in favor.

In some cases, as with very young children, foreigners, malingerers and insane people, where the subjective tests may be unreliable, it affords the most convenient method of determining ametropia.

The principle of the test is as follows: If rays of light be thrown into an eye from an ophthalmoscopic mirror held at a little more than a meter from the observed eye, the observer, looking through the sight hole, sees the fundus reflex. If now the mirror be rotated on its axis, a shadow is seen to move across the red reflex. The direction of the movement of this shadow, whether "with" or "against" the movement of the mirror on its axis, determines the character of the ametropia, though

not its amount. In low degrees the movement is quick and sharp and in high degrees it is slow and indistinct.

In making the test either the plane or concave mirror may be used, the plane mirror being more generally preferred. In either case it should have a diameter of 30 to 50 millimeters; if concave, a focal distance of 20 to 25 centimeters. The sight hole should be 3 or 4 millimeters in diameter, and to avoid reflections from around it, which are very annoying, its margin must be free from dust and chippings and should be blackened with a dead black. If the patient be over 40 years of age, sufficient dilatation of the pupil can be obtained by the use of cocaine; but if the patient be young, a mydriatic must be used, otherwise the refraction will vary with changes in the accommodation.

The room should be perfectly dark and the light used in the test come from through a small aperture opposite the brightest part of a flame situated above and back of the patient's head.

With these few general remarks we will take up first the practical use of the plane mirror in

MYOPIA.

The myope's far point, unlike the far point in emmetropia and hyperopia, is situated at a definite distance from the eye, and this distance corresponds with the focal length of the lens required to correct the myopia.

In skiascopy this far point is called the "point of reversal," and beyond this point the observer sees the movement of the shadow "against" the movement of the mirror on its axis, because he views an inverted image; but if the observer views the image from a point within the point of reversal, he gets an upright image, and the movement of the shadow will be "with" the mirror, though in both cases the real movement of light is "with" the mirror.

Therefore in practice the observer seats himself at one or two meters from the patient and finds that the shadow moves "against" the mirror; as he approaches the patient the movement becomes more rapid till the far point is reached, when the shadow's movement becomes indistinct, but approaching still closer the movement is sharply "with" the mirror. The distance from this point of reversal to the patient's eye is the focal distance of the lens required to correct the myopia.

In emmetropia, as rays emerging from the eye are parallel there is no far point so no point of reversal, and in myopia of low grade the point of reversal will be situated back of the observer, seated at one or two meters distance from the eye, consequently the shadow will move "with" the mirror. But by placing a convex lens before the observed eye it is rendered myopic in refraction. The distance of the point of reversal

is then found, and if it equals the focal length of the lens placed before the eye, the eye is emmetropic. If it exceeds it, the difference is the measure of the myopia present.

For example: The operator finds the shadow move sharply "with" the mirror even when he is three meters distant from the eye; he places a plus 1.00 dioptre lens before the observed eye and approaches till he finds the point of reversal at one meter distance from the eye, the case is emmetropia. If the point of reversal is found at 75 centimetres the entire myopia will be 1.50 dioptres; subtracting the 1 D. of myopia caused by the plus 1 D. lens, leaves minus .50 dioptres as the real measure of the myopia.

HYPEROPIA.

In hyperopia the emergent rays are divergent, so the far point is not a real one but is back of the retina. In applying the test a convex lens is placed before the eye to render it myopic. The point of reversal is then found, and its distance from the eye measured. This represents the amount of myopia produced by the convex lens and must be subtracted from the strength of the lens to give the amount of hyperopia.

ASTIGMATISM.

From what has preceded, it will be seen that the point of reversal of the principal meridians

may be found separately, the difference giving the amount of astigmatism present.

CONCAVE MIRROR.

In using the concave mirror the operator seats himself a little more than one meter from the patient.

With the plane mirror the apparent or immediate source of light thrown into the eye was an image of the real flame, situated as far back of the mirror as the mirror was distant from the light. Therefore rotation of the mirror on its axis caused a movement in the same direction of the retinal reflex.

When the concave mirror is used, however, an inverted aerial image of the original source of light is formed at the focus of the mirror. This forms the immediate source of illumination, and the rays diverge from this focus to the plane of the observed eye, to be brought to a focus again back of the retina. So any movement of the mirror on its axis causes an opposite movement of light on the retina.

Moreover, in using the concave mirror it must be remembered that the operator is constantly seated at one meter from the patient and does not change his position, and as in all tests the point of reversal is brought, by the aid of lenses, to this point, so in all cases minus 1.00 dioptre must be

added to the glass which brings the point of reversal to this distance from the eye.

MYOPIA.

The shadow moves "with" the mirror, the myopia therefore is of more than 1.00 dioptre. So concave glasses are placed before the eye till the point of reversal is brought forward to one meter's distance from the eye. Minus 1.00 dioptre being added gives the correction, or entire amount of myopia.

If the myopia present be of just one dioptre, there will be no movement of the shadow. If the myopia be less than one dioptre the movement of the shadow will be "against," in which cases convex glasses are placed before the eye till the point of reversal is at one meter from the observed eye.

HYPEROPIA.

The shadow moves "against" the mirror, convex lenses are added till the point of reversal is at one meter, then a minus 1.00 dioptre is added as before.

ASTIGMATISM.

The two principal meridians are tested separately and a minus 1.00 dioptre added to each result, and the difference of refraction in the two meridians equals the amount of astigmatism.

CHAPTER IX.

The Ophthalmoscope Relative to Refraction.

Ophthalmoscopy furnishes a second mode of supplementing the subjective determination of ametropia. It demands years of work to acquire this science, yet with those who have mastered it, it is reasonably reliable. Though very little information can be imparted through a book, as to the practical part of ophthalmoscopy, a few words on the technique may be of value.

As to illumination, the argand burner and tubular chimney are much in favor with some, while the condenser used for laryngoscopic examination placed over the tubular chimney seems to to be displacing the plain lamp, as it gives a clearer fundus.

Pure kerosene oil gives a good light, but now, happily, gas may be obtained in nearly every city of any size, and it will be found more convenient.

The lamp should be at the side of the patient's head on a level with the eye, and the nearer the lamp, eye and ophthalmoscope form a straight line, the less will be the angle of incident and reflected light; and consequently less rotation of the ophthalmoscope on its vertical axis will be

demanded. The ophthalmoscopic mirror should be concave and have a focal length of about nine inches. Before the examination of the fundus is begun it is desirable to examine the eye (by oblique illumination and by sunlight) to satisfy ourselves as to the normal condition of the cornea, iris and lens.

In the direct examination with the ophthalmoscope, the accommodation of the examiner should be relaxed and the pupil of the patient opened by a mydriatic. As skill is acquired, the use of the mydriatic is less important. The room of course must be darkened. When the examiner throws the reflected light into the eye and looks through the hole in the ophthalmoscope there is seen a red reflex due to the reflection of light by the choroidal vessels. This reflex must be studied until it resolves itself into a picture of the fundus, and this is best done by moving the head to and from the patient and examining at different distances and angles, to get familiar with the process.

The inverted image is obtained by the indirect method of examination, in which the observer, placed much farther back from the patient, obtains a reflex the same as in skiascopy, and then places a strong plus lens directly in front of the eye. This lens is drawn toward the ophthalmoscope until it is about its focal distance from the eye, when a small, aerial, inverted image, of the fundus, is seen in the air between the ophthalmoscope and

the plus lens, a short distance in front of the latter.

When the eye of the patient is emmetropic the fundus will be seen plainly in all meridians with the direct method of examination. The entrance of the optic nerve will appear as a whitish-red circle to the nasal side of the center of the retina, surrounded by the red retina and crossed by veins and arteries as they pass from the retina to the center of the nerve and disappear. In some cases as in albinos and negroes the want or excess of pigment alters this reflex to a great extent. The latter often presents a fundus dark and lustrous, with very little reflex whatever. When the pigment is highly developed in the choroidal stroma, and not so developed in the smaller vessels, the spaces between the vessels instead of being light, are dark grey or even black, and collected into masses between the interstices of the vessels. A very black striped appearance is thus given the fundus, which, when seen for the first time, often gives rise to some apprehension.

The fundus is examined a small part at a time, and the patient directed to turn the eye so that the different parts of the fundus are brought to view. Some few things are noticed in the fundus which, though not constant, are nevertheless of no pathological significance.

The disc is often surrounded, through part of its

circumference by a dark crescent which is produced by the edge of the choroidal coat showing through the retina and is called the choroidal crescent. Often there appears a white physiological cup occupying a part of the disc, narrowing toward the center of the nerve-head, which should be studied in order that it be not confounded with the funnel-shaped cup of atrophy or the abrupt marginal cup of glaucoma. One should remember, the stronger the illumination, the redder the reflex appears. Again the disc or papilla is not always round or approximately so, even in the emmetrope, as it is often possessed of a physiological elongation due to its anatomical make up, which resembles closely the optically elongated disc of astigmatism.

The greyish white appearance of the disc is produced by the mass of nerve fibres and the lamina cribrosa. Sometimes the medullary sheath of the nerve fibres does not end at the lamina cribrosa, but is continued on, giving a queer white striped appearance to the fundus. This condition is often seen in the rabbit, though it is rare in the human eye. The surface of the disc may be mottled, greyish-white, due to the fact that the medullary sheath is discontinued sooner on some nerve fibres than on others, which fact should cause no alarm. The distribution of the capillaries also varies in each disc.

The ring of white surface generally seen near the edge of the disc is formed by the connective

tissue of the sheath of the nerve as it continues upward to the innermost part of the sclera.

The veins are darker and about one-third larger than the arteries; both show a distinct white line following their course which seems to lie upon their surface. This line is much more plainly seen when the artery is observed. There is no pulsation seen in the arteries nor in the veins except over the disc, and that is not frequently noticed. The yellow spot or macula lutea is situated to the temporal side of the disc, its border is best seen with the indirect method, and appears, with the inverted image, as a dim silvery ring to the inner side of the nerve. The fovea centralis is the central part of the macula and will appear as a dark spot in the macula; it is better seen in some eyes than others, and always better with the direct method of examination. This, then, is the picture presented by the emmetropic eye.

When an emmetrope looks into the eye and sees a clear image over all parts of the fundus without using his accommodation, he is aware at once that he is looking at an emmetropic eye; and if the fundus is indistinct, but brought out clear, by use of the accommodation, it is plain that the eye must be hyperopic. If again the fundus is indistinct and cannot be cleared up by accommodation, it is evidently a myopic eye or one that will present a pathologic condition.

There are other things which help in determining the condition of the ametropia. In hyperopia the disc appears smaller with the direct image, and in cases of considerable degree the disc is red, even very red, and poorly defined at best.

It is then only necessary to relax the accommodation and turn on plus lenses in the ophthalmoscope, until the strongest plus glass is employed with which a distinct fundus is obtained and the measure of the hyperopia is taken. In order to measure the hyperopia with the ophthalmoscope, it is not necessary, in most cases, to paralyze the accommodation of the patient. This point, though much disputed, is capable of clinical demonstration, and is thought to be due to the fact that the attention of the hyperope is not attracted to any point of fixation as in the refraction with lenses, and the accommodation therefore relaxes.

In myopia the disc appears larger, when using the direct method, and usually whiter and clearer of outline, than in hyperopia. When of high degree the disc looks displaced somewhat and its fibres are curved or the circumference is even distorted, especially on the temporal side. The choroid is also drawn away from the disc on the temporal side, so that a whitish crescent appears. If the myopia is of very high degree, the vitreous often detaches itself from the retina, and even the retina may detach from the choroid; hemorrhages

occur, and hence the picture in high degrees of progressive myopia may be of a great variety.

In determining the amount of myopia with the ophthalmoscope we use the weakest minus glass that gives a clear image of the fundus and say it is the measure of the myopia. In using the indirect method, the relative size of the disc in myopia and hyperopia is reversed; the disc in high degrees of hyperopia being large, diminishing directly with the refractive anomaly, decreasing as emmetropia is reached and on down through myopia. Again, with the indirect method in astigmatism the image of the disc appears elongated in the direction of the meridian of LEAST curvature when the plus lens is held near the eye, and it is by this means that the physiologically elongated disc can be told from the elongation of the disc due to astigmatism.

Astigmatism is determined objectively by the ophthalmoscope. As the refraction of the different meridians differs, with the direct method, the observer will not receive a clear image of all the fundus at once, neither will a plus or minus glass bring out both meridians clearly at the same time. Again, the fundus in the meridian of the greatest curvature appears larger or magnified and the round papilla assumes a vertical oval at the axis of greatest curvature, or (in astigmatism with the rule) at 90° in either the myopic or the hyperopic variety.

If an eye were emmetropic in the 180° plane and myopic by 3.00 dioptres in the 90° plane, the observer is adapted only to the 180° plane, and will see distinctly the fundus over the 90° plane. The enlargement is also different in the different planes or meridians. The meridian of least refractive power is seen with a weaker or stronger glass (as the case is compound hyperopic or compound myopic astigmatism) than the meridian that is at right angles to it. The enlargement of the fundus occurs through the meridian of greatest refractive power.

In hyperopic astigmatism with the rule the disc presents an oval longer at 90° with the direct method, yet the disc becomes wider at axis 180° when viewed by the indirect method (when the plus lens is held near the eye), and as the plus lens is drawn out from the eye the disc becomes relatively smaller through the horizontal meridian. When the distance between the lens and the first principal point of the eye is equal to the focal distance of the lens, the disc becomes round, and if the lens is farther drawn out, the papilla takes on a vertical elongation again.

From the foregoing it is evident that the aerial image of the disc contracts relatively, in the meridian of least refraction, and enlarges relatively, in the meridian of greatest refraction, as the plus lens is drawn out from the eye; therefore, in hyperopic

astigmatism the horizontal diameter, of the aerial image, is diminished relatively, as the lens is drawn out from the eye, and in myopic astigmatism the vertical diameter of the aerial image is relatively enlarged under like withdrawal of the lens, provided in both cases the astigmatism is with the rule.

In mixed astigmatism the aerial image enlarges in the direction of the myopic meridian and contracts in the direction of the hyperopic meridian as the plus lens is withdrawn.

The reason that this phenomena is not more apparent clinically is because in astigmatism there is often an accompanying physiological elongation of the disk at 90°, in which case the diameter of the papilla at 180° is much decreased relatively speaking (with the indirect method), while the plus lens is held its focal distance from the eye, and instead of a round disc, one is seen that presents an elongation at 90° with a distinct bulging on both sides at the axis of 180°.

To correct astigmatism with direct opthalmoscopic examination the lens which gives a clear image in each meridian is the measure of the ametropia in the opposite meridian, and the difference is the amount of astigmatism.

Irregular astigmatism is determined with the ophthalmoscope by the peculiar and twisting outlines of portions of the fundus and the indistinctness of part or all of the picture. Often one meridian may

be corrected and some useful vision given, and it becomes our duty to attempt to do this especially when both eyes are affected.

In conical cornea and some other high degrees of ametropia from other causes, the fundus looks like a shining, glistening ball of red, surrounded and buoyed up by a dark fluid. When the proper correcting lens is turned into the aperture of the ophthalmoscope the peculiar picture clears up instantly. In determining the exact axis of astigmatism with the ophthalmoscope, if a match or slight rod is held between the flame and the mirror, the shadow of the rod is not equally defined in all meridians, and the region of the least and greatest distinctness will locate the axes practically well.

CHAPTER X.

Extrinsic Eye Muscles and Their Anomalies.

The four recti muscles of each eye arise around the bony circumference of the foramen opticum and run forward to be inserted into the sclera. They form a funnel with its apex situated at the foramen opticum and give a broad tendonous attachment to the sclera, which is much thickened thereby.

The muscle that attaches to the sclera, to the inner side of the cornea is called the internal rectus. The one that attaches to the sclera to the outer side of the cornea is called the external rectus. In the two eyes these four muscles form two pairs. The internal of one eye and the external of the other working together in the excursions of the eyeball, and yet the two interni work together when convergance is required.

The external rectus of the right eye and the internal rectus of the left eye turn the eyes to the right; and the external rectus of the left eye and the internal rectus of the right eye turn the eyes to the left.

The two remaining rectus muscles of each eye run forward and outward and are inserted into the sclera one above and the other below the cornea, and are called respectively the superior and inferior rectus. In excursions of the eye demanding action of these muscles, the two superior recti and the two inferior obliques act in unison; and the two inferior recti and the two superior obliques also.

In all excursions of the eye Tenon's capsule acts as a socket for the enarthrodial joint.

The superior rectus turns the eye up and in. As it runs forward to be inserted into the sclera it forms an angle with the sagittal axis of the eyeball by running outward as well as forward. It pro-produces adduction as well as elevation.

The inferior rectus turns the eye down and also for the reason explained in speaking of the superior rectus, draws the corneal portion of the eye in, that is, acts as an adductor.

Two other extrinsic muscles are given to each eye. The superior oblique which also arises from the margin of the foramen opticum, but its virtual insertion is the trochlea, at the upper and inner wall of the orbit. This muscle passes out over the eyeball to be inserted into the sclera behind the center of the eyeball. The trochlea is relatively higher than the insertion of the muscles. A contraction of this muscle would then tend to throw the cornea down, rotate the top of the axis of 90°

over toward the bridge of the nose, and abduct the anterior half of the eyeball.

The inferior oblique arises from the lower margin of the orbit, near its inner boundary. It runs out and up and is inserted into the sclera behind the equator, in about the horizontal meridan. The action of each of these inferior oblique muscles on their separate eye, is to rotate the lower extremity of the axis of 90° toward the nose (opposite to the rotation produced by a contraction of the superior oblique), to elevate the cornea and to abduct or turn the anterior or corneal portion of the eyeball out.

Many of the tests for paralysis of the oblique muscles are made dependent on the rotation of the retina on its sagittal axis, by the contraction of these muscles. In this chapter we will make the diagnosis on the abduction produced by the obliques as compared with the adduction produced by the superior and inferior rectus.

We have then three pairs of muscles.

First—The internal and external rectus, which rotate the eye about its vertical axis.

Second—The superior and inferior rectus, which turn the eye principally about its horizontal axis and produce some convergence.

Third—The superior and inferior oblique, which rotate the eyes about their sagittal axes and produce some divergence.

In considering the diagnosis and treatment of the anomalies of the eye muscles, we have chiefly two conditions to meet.

Insufficiency—Where the muscle, though insufficient for the work, is still so adjusting the retina of each eye as to produce images on the same relative part of each retina.

Strabismus—Where the insufficient muscle gives up the hopeless task of overwork and allows one eye to wander far out on any of its excursions and remain there.

It is evident that the diagnosis of a squint and the muscles at fault can be easily made after a careful study of the origin, insertion and action of these several extrinsic muscles. The difficulty will be to diagnose the insufficiency where the muscle, though of inferior strength, is still by extra effort doing its work. This is done by placing a prism in front of one of the eyes (preferably the left), and a red glass in front of the right. The prism throws the object seen by the left eye toward its apex; therefore, the image of the left eye appears higher than the image of the right eye. It is now impossible by any effort, to fuse the images, and the insufficient muscle accepts the situation, ceases its over-exertion, and allows the eyes to swing into their true relative position, which position, indicates the comparative strength of the muscles. The position of the two images thus produced will determine the muscle at fault.

For instance, to test the internal and external rectus muscles, which are most frequently at fault, having placed an 8° prism base down over the left eye and the red glass over the right eye, the patient is directed to look at the lighted candle. Two candles are seen. The higher and white one by the left eye, and the lower and red one by the right eye.

Now if the internal recti as a pair are perfectly balanced with reference to the external recti, one image will appear directly above the other; provided the prism is placed carefully in a perpendicular position. If these two lights are not one directly over the other, the relative position of the lights refers us to the weak muscles; that is, if the internal recti are relatively too strong, a slight convergence is produced, we will say for simplicity, in the right eye alone (though both eyes are converged).

What has this done? Well, the part of the retina at the left of the macula (which in the right eye had been placed so as to receive the retinal impressions of objects to the right of the center of the patient's field of vision), has been drawn around and occupies the place the macula formerly occupied. And what is the effect? The object is oriented subjectively out in space to the right hand side of the center of the field of vision and is there seen. Then the image of the right eye stays to

the right, and is, in this case, the red and lower image, while the white higher image of the left eye is of course seen to the left. This is called homonymous diplopia, and indicates an abnormal amount of convergence which results from an insufficiency of the external rectus muscles.

When on the other hand, with the prism and red glass remaining the same, where the internal recti are insufficient, we will say for simplicity, the right eye only is turned slightly out (though both are so turned), the retina to the right of the macula is drawn around where the macula should be, and this part of the retina has been receiving images from objects to the left of the center of the field of vision, and the object is oriented subjectively over to the left, or across the path of the image of the left eye. The red lower light is then seen to the left of the white higher light of the left eye and this is called crossed or heteronymous diplopia and always indicates divergence or insufficiency of the internal rectus muscles.

In the first instance prisms are placed base out until the insufficient external rectus is strengthened up till one image is straight over the other. In the second case, where the diplopia is crossed, we put the base of the prisms over the insufficient internal rectus until the image is brought back to the right far enough to be directly under the white higher image of the left eye. The marking of the prism

required in this procedure is the degree of insufficiency of the muscle corrected. Now having seen that these muscles are normal or are corrected up with the prisms, we raise the candle (which has hitherto rested level with the plane of the eyes) to the upper field, then if the muscles which raise the eye are normal (the superior rectus and inferior oblique), the images will stay at the same distance from each other; but if one eye lags in this upward excursion the images will separate; and as the eye that does not follow up will receive the images lower down on the retina than the eye which follows the candle up more fully; this image will be oriented subjectively higher than the other (with relation to the distance which they were apart when they started). Then the higher image belongs to the eye with the affected muscle. Again, we know from the first of the chapter, that of these two muscles now acting, while they both elevate the eye, the superior rectus produces convergence and the inferior oblique produces a corresponding amount of divergence. We have also learned that with convergence, homonymous diplopia results. We determine insufficiency of one of these two muscles, because the images (relatively) separate in the upper field, and if the separated images are homonymous we diagnose an over amount of convergence in the upper field which is produced by the adducing action of the superior rectus when not

balanced by the abducting power of the inferior oblique. Hence we know the inferior oblique is at fault when we have images separating in the upper field and homonymous diplopia. Contra, when the images separate in the upper field and heteronymous diplopia is produced, we know that divergence in the upper field is produced by the inferior oblique, when the superior rectus is not counterbalancing its diverging power. Hence we know that the trouble lies with the superior rectus, which is insufficient.

Now the candle is again placed on a level with the eye and lowered into the lower field. If the images stay one above the other and at the same relative distance, the muscles which turn the eyes down (inferior rectus and superior oblique) are correct. Again, if the images separate in the lower field, one or both of these muscles are insufficient and the lower image belongs to the lagging eye.

We have already learned that the inferior rectus does the converging in the lower field, and that homonymous diplopia results from convergence. Hence, if the separating images are homonymous in the lower field, the trouble is from insufficiency of the superior oblique. If the images are heteronymous and separating in the lower field, the inferior rectus is insufficient. In this simple way the exact condition of the muscles is easily obtained.

As to the correction of the insufficiencies, the case where the internal rectus is insufficient is by far the one more often demanding correction. When this muscle is insufficient for distance the insufficiency will be greater when any work demanding much convergence is performed, as reading, sewing, etc., whereas, a few degrees of insufficiency of the external rectus will not be a serious anomaly and is even acceptable in the case of the myope, who does not make the demands on accommodation to assist convergence that the emmetrope does. Unhappily, however, the opposite condition of affairs, or insufficiency of the interni is the rule with myopia, while the hyperope is more often found with insufficiency of the externi. In reality the insufficiency of the internal or external recti affects each eye equally when it occurs.

When starting this test with the prism, base down over the left eye, the image of the left eye is thrown higher than the image of the right eye and if the right eye lags, in the upward excursion, the image of the right eye first approaches, passes, and then separates from the white image of the left eye as the candle is lifted higher. This was a virtual separation from the start, but the first of the movement is neutralized by the effect of the 8° prism base over the inferior rectus of the left eye. When in the lower field the left eye lags, the images first approach and then separate, which is virtually a

separation from the start on account of the prism 8° base down in front of the left eye.

In prescribing prisms when a considerable amount of insufficiency exists, the prism is divided and put one half over each eye, base over the muscles to be strengthened. In 8° insufficiency of the external rectus muscles, 4° is placed in each eye base over the external rectus.

In prescribing prisms for the superior and inferior rectus muscles it is better to divide the prism. In 10° insufficiency of the superior rectus of right eye, 5°, base up, is placed over the superior rectus of the right eye, and 5°, base down, over the inferior rectus of left eye. In this way the object of one eye is lowered by 5° and the object of the other eye raised by 5°, whereupon they meet on a plane and the images are fused. The correction of the oblique muscles, when insufficient, has not proved practical. It is advisable to limit the use of prisms to insufficiencies.

In strabismus where an operation will not be submitted to, a correction of the ametropia will be of great service and is generally considered complete without the addition of prisms, and in paralytic strabismus nothing could be more absurd than the wearing of a prism.

Paralytic squint may be easily tested without the prism in front of the eye by remembering that diplopia occurs only when the eye is rotated in a

direction demanding the co-operation of the affected muscle; that the images will separate when the object is moved in the direction of the action of the paralyzed muscle and the image of the affected eye travels further away from the image of the sound eye when the object is so moved.

The secondary deviation (when the sound eye is covered and any object demanding the action of the affected muscle is fixed by the affected eye) is greater than the primary.

In testing the superior and inferior rectus muscles in the lateral plane, a prism of 20° is placed base over one internal rectus muscle and if this does not produce diplopia another prism is placed base over the other internal rectus muscle and these prisms are strengthened until two candles are seen. Now if the images stand equally high the superior and inferior recti muscles are considered in balance.

The test in the upper and lower fields are, however, more reliable.

Insufficiency of the external rectus muscles is termed esophoria. Insufficiency of the internal rectus muscles is termed exophoria. Insufficiency of the inferior rectus muscles is termed hyperphoria. Insufficiency of the superior rectus muscles is termed cataphoria.

Often the superior and inferior recti and the superior and inferior oblique muscles are tested as herein described, except that the prism used to pro-

duce diplopia is placed base in over the internal rectus muscle and lateral images are produced; (after having placed in the frames the prism correcting the insufficiency of the lateral muscles if any exists). The images then separate in the upper or lower field from the instant either eye starts to move more slowly than its congener.

When the external rectus muscles are insufficient a mydriatic should be used in every case of refraction, whether the patient is hyperopic or myopic; in hyperopia that we may determine the *full* amount of ametropia (a full correction of which will remedy much of the muscular trouble), and in myopia that we may avoid over-correction.

When the internal rectus muscles are insufficient, a mydriatic is also imperative, as this insufficiency often causes spasm of the accommodation, and emmetropic eyes appear myopic, myopic eyes appear more myopic, and hyperopia becomes all latent.

For a patient with insufficiency of the interni: if hyperopic, we correct both muscles and ametropia, or the muscles only; if myopic, a full correction is extended for distance and reading, if accommodation permits.

When the external rectus muscles are insufficient, hyperopia is always fully corrected and myopia only partly corrected for reading, though often a full correction for distance is accepted.

Nothing is more gratifying than the effect of a carefully graduated tenotomy in many of these cases.

CHAPTER XI.

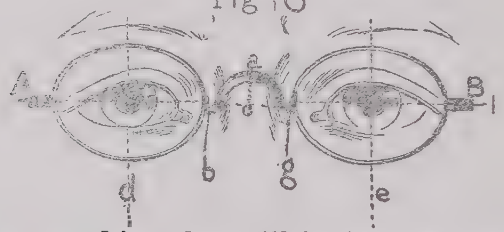
Measuring of Frames.

The importance of measuring frames correctly is evident when we consider that by them the lenses are held in front of the eye in either a proper or an improper position. As an example of the harm done by the giving of an incorrect pupillary distance, we will instance the case of a myope with a pupillary width of two and four-sixteenths who has been given a frame carrying a pupillary distance of two and three-sixteenths, the lenses are thereby decentered with relation to the eye so that a prism base out is placed over the external rectus muscle, which is already, generally, oversufficient for near work in myopia.

The first thing to be considered in measuring the face for a spectacle is the pupillary width. When the glass is to be used for near work only, it is well to request the patient to look at the central portion of the forehead of the measurer and the pupillary distance taken while this fixation is maintained. When the glass is to be worn for distance only, the patient may be requested to look at a distant object over the right or left shoulder of the measurer, and the pupillary distance then taken, which will generally be two-sixteenths of an inch greater than in the foregoing case.

In dealing with an eye with no muscular anomaly, many request the patient to fix his view as first mentioned in this chapter, and add one-sixteenth of an inch to that measure if the frames are for constant wear, or one and one-half sixteenths of an inch for distance only. In adding one-sixteenth of an inch to the pupillary distance, taken while the patient fixes the forehead of the measurer, the mean for general work will be found approximately accurate. The exact center of the pupil should be carefully sought and measure taken with a steel rule, which is divided into sixteenths or thirty-seconds of an inch.

Fig 16



The next thing that will invite our attention is the height of the bridge. By this is meant the distance above or below the pupillary line A——B (Fig. 16), at which the bridge is wished to rest on the patient's nose, or the distance of the line c——a (Fig. 16).

The lower we wish the lenses to drop toward the malar bone, the greater must be the height above, of the bridge, and the higher the

bridge of the nose the greater is the height above of the bridge. When glasses are to be used for reading only (the height above of the bridge being sufficient to drop the lenses) the patient is thereby relieved of the great inconvenience of bending the head forward or of elevating the book. In case of a very flat nose the bridge may be set below the line of the pupils in order to lift the pupillary line of the lenses up to the pupillary line of the eyes.

The position of the crest is to be considered and it is evident that when the crest of the bridge is thrown back, the lenses must be thrown forward and vice versa. In case of long lashes and prominent eyes, the crest of the bridge must be set back far enough to throw the lenses forward sufficiently to enable the lashes to pass without interference, otherwise the lenses are continually covered by the moisture from the cilia, and the patient very greatly annoyed by this interference.

When the eye is deep set and the cilia short, if the bridge were prescribed on plane there would be too much space between the cornea and the lens. In this case, therefore, the bridge is thrown forward and the lenses thus pushed back nearer the eye. The width at the base of the bridge (b to g, Fig. 16) must be great enough to just allow the nose to set between its sides, neither being tight nor loose. This is measured by holding the steel rule on top of the bridge of the nose and estimat-

ing the width at the base of the nose bridge, where the frames are to come.

By the angle of the crest is meant the angle which the crest of the bridge makes with the plane of the lenses. The angle of the crest in Fig. 17

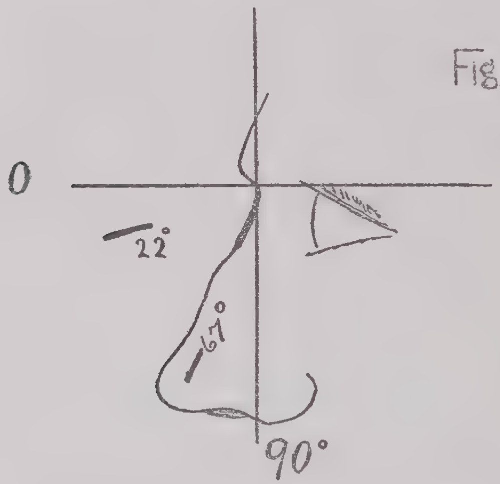


Fig. 17

shows a nose demanding a crest, at an angle of 45°, and this angle will fit a large majority of cases, and no other need be prescribed, unless the nose protrudes directly forward so as to demand an angle of less than 25°, or drops so flat as to require an angle of more than 60°; in these extreme cases it is well to specify the angle counting from the horizontal axis at zero to the perpendicular axis at 90°. The large variation in the angle of the crest is received, happily, by so many differently shaped

noses, because of the round under surface of the bridge as generally made.

The width of the temples is measured back where the temples will first touch the head, or nearly an inch back from their junction with the frames.

As to the length of the temples, it is only when a very long or very short rider is needed that any particular instruction is required, as the temple, in a riding bow at least, is so easily changed in length by a gentle bending.

The straight temple is to be prescribed where the frames are to be often removed, as for reading glasses; the riding bows, where more continued wear is demanded. A skeleton frame is one where the binding does not surround the lens and it gives in beauty what it lacks in stability. For those unable to wear eye-glasses it presents an available alternative to the plain riding bow. As to the style of bridge, the saddle bridge is a general favorite and is usually furnished where none is specified. The C bridge may be prescribed for straight temples and especially for cataract glasses, as it is not so easily bent in the folding of the frames. The X bridge is of use in some cases, the chief indication being a flat nose.

The angle that the temples make with the frames should be determined when fitting the glasses to the face of the patient, at which time the

beak of the temple may be gradually filed until a proper spread is produced. As to the size of the eye, a number one eye is generally used with a bound lens, except in cases of bifocal lenses or cataract glasses, where a naught eye is preferable.

In skeleton lenses a naught eye is in general use and the long oval is a favorite, especially for tall or slender people. The larger sizes, double naught, etc., are considered more beautiful, but it is seldom that the features permit of their use without just objection. The small numbers, two and three, are not much used of late.

In measuring for eye-glasses the pupillary distance is taken the same as for spectacles. The thickness of the nose where the top of the guard and where the bottom of the guard will come is carefully measured. The average guard may be regarded as about ten-sixteenths to twelve-sixteenths of an inch long, and in giving the width above and below, one should specify whether the measure is intended to be when on, or off, the nose. When prescribing width for guards when not on, two-sixteenths to three-sixteenths of an inch is allowed for spring, according to the firmness of the nose bridge. These guards will be easily changed by a pair of parallel bar forceps at the time of fitting them to the face, so that they will exactly meet the contour of the sides of the nose. The spring may be easily loosened or tightened with

the bending forceps. The bending forceps present one lip convex and the other concave, so that when shut, these lips form the arc of a small circle.

Many devices are made to enable those with an unfavorable nose, to wear eye-glasses, and one must choose as their experience teaches them.

The skeleton eye-glass again sacrifices stability for beauty, but possesses one admirable quality, that is, the holes may be drilled above the center of the lenses when to be used only for reading, and thus the lenses are lowered, as when in a riding bow the bridge is placed high above the pupillary line. When the brow is very prominent, the crest of the spring is set forward a corresponding distance, and when very receding the crest of the spring should be set back so as to rest on the bow, as the stability of an eye-glass greatly depends on this one point.

Any acceptable shaped spring may be used, the round one being in great demand at present. Again steel is more preferable for young people using eye-glasses, while gold enjoys first rank for the old. In riding bows the metal is largely determined by the Louis D'Or. Probably the neatest combination is the steel skeleton eye-glass, at least for those under 40 years of age. Gold and steel are easily mended when broken, while aluminum, though light, cannot be repaired. This should be considered in ordering frames for rough use.

CHAPTER XII.

General Remarks with Decentering of Lenses.

When it becomes necessary to put a prism over an eye muscle or a pair of eye muscles, instead of grinding a prism in the lens, the lens is often decentered so that it produces the prismatic effect desired. It has often been laid down as a rule that one may decenter one-half of one degree to the dioptre, and that the ratio increases as the dioptres, provided that the lens is kept small. The smaller the lens is in contour the greater is the prismatic effect that can be produced by decentering it.

Annexed is a table used by some of our most reliable opticians, which differs very slightly from Maddox' rule.

Table showing number of millimeters to decenter spherical lens in order to add a prism of from $\frac{1}{4}°$ to $2°$:

DIOPTRES	$\frac{1}{4}°$	$\frac{1}{2}°$	$\frac{3}{4}°$	1°	2°
0.25					
0.50	4.6				
0.75	3.				
1.00	2.3	4.6			
1.25	1.8	3.7	5.5		
1.50	1.5	3.1	4.5		
1.75	1.3	2.6	3.9	5.3	
2.00	1.1	2.3	3.4	4.6	
2.25	1.	2.0	3.0	4.1	
2.50	.9	1.8	2.7	3.7	
2.75	.8	1.7	2.5	3.4	
3.00	.75	1.5	2.3	3.1	
3.25	.7	1.4	2.1	2.8	5.7
3.50	.65	1.3	1.9	2.6	5.3
4.00	.6	1.15	1.7	2.3	4.6
4.50	.5	1.	1.5	2.1	4.1
5.00	.45	.9	1.3	1.8	3.7
5.50	.4	.8	1.2	1.7	3.4
6.00	.35	.7	1.1	1.5	3.1

In giving a pupillary distance of too great or too small an amount, the lenses are unintentionally decentered. Take a myope, given too narrow a pupillary distance, where the rays of light entering the eye must pass externally to the principal axis of the lens and the lenses act as prisms base out or over the external recti, (which muscles are generally, relatively too strong in myopia to allow of free convergence), here the trouble caused by the prisms is more than the benefit derived by the correction of the ametropia.

If, however, the error was made in the opposite direction, and the pupillary distance given was a little too great in myopia, so the prisms would be set base in, convergence would be rendered easier and the greatest satisfaction possible would be obtained. In hyperopia, where the internal recti are generally overstrong, the error is less serious if too narrow a pupillary distance is given and the external recti strengthened; yet it is better exact, unless insufficiencies require correction.

In reasoning these results one has only to remember that in a minus glass the apex of the prism is in the center of the lens, and in a plus glass it is at the periphery.

In prescribing prisms, if one has a reliable optician, it is preferable to state the amount of prism required and in what direction the base should be placed and let the optician grind it in with the lens according to his own rule.

In considering prisms there is a question, which is an important one, and that is that the prisms now ground by all the large factories in this country are ground on the prism dioptre scale, which is based on the rule that a one dioptre lens should be decentered ten millimeters in order to produce the effect of a 1° prism.

A two-dioptre lens would require a decentering of five millimeters for each degree of prism, and so on.

Now the American trial cases in the market contain prisms based on this system, while the foreign trial cases are made on the old plan.

Physicians ought to take some action on this matter so that their set of prisms should be replaced with others based on the prism dioptre system, and a universal rule of decentering, in accordance with it, be adopted by all opticians when filling prescriptions.

As to the preferable mydriatic to use in general refraction the one already referred to, (one grain each of cocaine hydrochlorate and homatropine hydrobromate to the dram of water,) is serviceable and efficient in nearly all cases of refraction, but when it is determined from the use of other instruments of precision that the ametropia is yet unmasked, sulphate of atropine (four grains to the ounce) dropped in the eye three times a day for

three or four days will prove satisfactory and certain in its results. A tablet of cocaine and homatropine has been placed on the market in the form of a refraction disc. It has not as sure an action as the homatropine solution, but will keep longer, and claims attention from those doing a limited amount of refraction, in whose hands the solution would spoil before being used. The solution will keep well, forty days at a temperature of 65° Fahrenheit.

The visual acuity for distance is not changed by instillation of a mydriatic in emmetropia or myopia, but is lowered in hypermetropia and astigmatism. Visual acuity is often increased to normal, in spasm of accommodation, during the use of atropine, when, if hyperopia be present, it will decrease proportionately to the amount of the hyperopia.

By anisometropia is meant a difference in the refraction of the eyes to such an extent as to give perceptibly different sized images.

Anti-metropia is an anisometropia where one eye is hyperopic and the other myopic.

Congenital anisometropia is often of high degree, six to ten dioptres, and is due to faulty devel opment of one or both eyes. It often occurs with imperfect development of one side of the head.

Vision is binocular in proportion as the anisometropia is not of too high a degree. Vision may be accomplished by the better eye, the poorer one

rapidly becoming amblyopic. Some few use each eye alternately.

In considering anisometropes, the prism may be used to see if both eyes participate in vision. The hyperopic anisometrope cannot use the accommodation in one eye more than in the other, hence he is unable to correct the difference of hyperopia in the two eyes; neither, when accommodating does he get the same idea of distance from the convergence produced, though it be equal to the emmetrope's convergence. This would tend to show that convergence is not the only factor in the judging of distances. In correcting anisometropia, when the eyes are used alternately or when one eye is used more than the other, the better eye is to be corrected as the requirements of work and ametropia demand, and the same correction placed over the other eye, so that their relative refraction is not changed.

As an exception to this rule may be cited the case that is emmetropic in one eye and myopic in the other. To this person a correction is made of the myopic eye and a plain glass given to the emmetropic eye. When one eye is myopic and the other hyperopic, the myopic eye may be corrected and the hyperopic eye given a plain glass. This will evidently be accepted for distance and may or may not be used for near work. The inclination might be to correct the hyperopia of the one eye or

to give the emmetropic eye in the first instance a plus 3.00 dioptres glass for reading, to adapt it to the same near point as its myopic partner, but unhappy results of such a correction are certain to follow, provided both eyes participate in the visual act. When only one eye is used, or has vision, it is the only one inviting attention.

Many of these cases of anisometropia admit of no rule and must be given the correction indicated by experiment.

We often have trouble with the accommodation not due to the diminution, in the possible amount of dynamic refraction, that can be exercised at any given time. From accident, a rupture of the zonula may result, after which the lens assumes its greatest convexity and remains always the same, producing a constant blurring, of all distant objects, seen by the affected eye.

Again anything which affects the working of the ciliary muscles, affects the usefulness of vision. Paresis of the accommodation results from such causes as contusions of the eye, and has resulted from the operation of tenotomy, and even the forcible dilation of a lachrymal structure. Generally the pupil changes with the interference of accommodation, and in paralysis of the accommodation the amplitude of convergence is lessened.

The principal symptoms of paresis, or paralysis are, recession of the punctum proximum, and

micropsia. Outside of contusion and injuries, paresis or paralysis occurs as a precursor of sympathetic ophthalmia, and they are often concurrent with syphilis, diabetes, severe affections of the central nervous system, (as Tabes Dorsalis in which the Argyle Robinson pupil is noticed), and poisoning from putrid meats, especially imperfectly salted pork, and fish, as well as from the use of cocaine, atropine, etc. The accommodation weakens after exhaustive diseases, profuse hemorrhages or any great excesses. Clonic spasm of accommodation occurs during fixation and convergence, and yields when an ophthalmoscopic examination is being made.

It is not a pathologic process, though if voluntarily kept up for a long time will give much annoyance, as testifies any person during his first month of energetic work with the microscope.

Tonic spasm may be called pathologic spasm and may affect one or both eyes or one eye more than the other. The principal symptoms are, approximation of the punctum remotum, micropsia, and the reduction of the amplitude of accommodation (which is a common symptom with paresis or paralysis). The patient complains of pain over the eyes and temples, and of a feeling of constriction through the forehead. The pupil is generally small, as compared with the pupil of paresis.

When the visual acuity is improved by the

milder mydriatics it strongly indicates spasm. Conjunctivitis, keratitis, sympathetic ophthalmia and many other inflammations of the eye, reflexly stimulate tonic spasm of the accommodation. It also occurs with hyperæsthesia of the retina and with insufficiency of the internal rectus muscles.

Meningitis and other acute diseases of the brain cause convergence and spasm of accommodation, with contraction of the pupil. Among the drugs that produce spasm, eserine the alkaloid of calabar bean demands first attention. From a one-fourth of one per cent., to a one per cent., solution is generally used, and the sulphate is the preferable salt.

Hydrochlorate of pilocarpine also may be used, but is not as powerful as the former and does not alter the static refraction of the eye. Among drugs that produce paralysis of the accommodation, sulphate of atropine is the most powerful, four grains to the ounce being sufficient to paralyze the accommodation completely. It is generally instilled three or four times a day for four or five days, when spasm is to be reduced. Homatropine and cocaine both act to paralyze the accommodation and have been previously referred to, and when properly used in combination, they will very seldom be found insufficient to suspend accommodation, even in the most troublesome cases.

The following cases are selected from the clinical patients presented at the University clinic and are of such a variety as to illustrate the more important principles in prescribing lenses.

The cases here recorded were at the time of refraction living near the hospital, and in each case they were requested to report when the result obtained was not satisfactory. When no report was returned it was assumed that relief was obtained, and where return was made it was duly noted. The strength of the prism overcome by the external rectus muscles was taken before the use of the mydriatic and while the patient was fixing at about the near point.

CASES.

CASE 1.—Anna B., aet 35. Occupation, Teacher. Amplitude of accommodation, 6 D. Punctum Proximum, 240 m. m. Muscles normal. Internal recti overcame 30° prism, base out.

Symptoms—

Inability to do near work, headache after trying.

Refraction—

O. D. + 2.00 D. sph.

O. S. + 2.00 D. sph.

Treatment—

O. D. + 1.50 D. sph.

O. S. + 1.50 D. sph.

To be worn constantly. Patient requested to return if not satisfied.

Result—

No report ever made.

CASE 2.—Jane C., aet 8. Occupation, School girl. Amplitude of accommodation, 14 D. Punctum Proximum, 72

m. m. Muscles. Insufficiency of external recti of 40°. Had been troubled with periodic squint. Internal recti overcame 60° prism, base out.

Symptoms—

Constant headache.

Refraction—

O. D. + 3.75 D sph.

O. S. + 4.00 D. sph.

Treatment—

Patient given + 1.50 each and gradually increased to full correction. To be worn constantly.

Result—

Headache was relieved when abont one-half the correction was worn.

Case 3.—John L., aet 18. Occupation, Student. Amplitude of accommodation, 11 D. Punctum Proximum, 91 m. m. Muscles normal. Internal recti overcame 35° prism, base out.

Symptoms—

Slight headache after near work.

Refraction—

O. D. + 1.25 D. sph.

O. S. + 1.25 D. sph.

Treatment—

O. D. + 75.

O. S. + 75.

To be used for near work only.

Result—

Headaches ceased.

Case 4.—Arthur B., aet 21. Occupation, Student. Amplitude of accommodation, 10 D. Punctum Proximum, 100 m. m. Muscles. Insufficiency of internal recti of 4°. Internal recti overcame 30° prism, base out.

Symptoms—

Headache after study.

Refraction—

O. D. + 1.00 D. sph.

O. S. + 1.00 D. sph.

Patient was wearing + 1.00 in both eyes for near work.

Treatment—

Given 4° prism base in for near work only, and exercise for internal recti.

Result—

Patient complained some, but was better able to study.

CASE 5.—Minnie B., aet 14. Occupation, Servant girl. Amplitude of accommodation, 11 D. Punctum Proximum 97 m. m. Muscles normal. Internal recti overcame 35° prism, base out.

Symptoms—

Was often dizzy and had suffered from headache, (after near work), which of late was nearly constant.

Refraction—

O. D. + 3.00 D. sph.

O. S. + 10.00 D. sph.

Treatment—

Was given + 2.00 in both eyes and these lenses were increased to + 3.00 in both eyes, after two weeks.

Result—

Good.

CASE 6.—Lydia Mc., aet 30. Occupation, Housewife. Amplitude of accommodation, 6 D. Punctum Proximum, 110 m. m. Muscles normal. Internal recti overcame 35° prism, base out.

Symptoms—

Indistinct distant vision, could read without any trouble.

Refraction—

O. D.—3.00 D. sph.

O. S.—3.00 D. sph.

Treatment—

Given — 3.00 both eyes for distance only.

Result—

Good.

CASE 7.—Kate E., aet 18. Occupation, Student. Amplitude of accommodation, 10. D. Punctum Proximum, 70

m. m. Muscles 10° insufficiency of the internal recti. Internal recti overcame 25° prism, base out.

Symptoms—

Severe headache continually, but worse after studying.

Refraction—

O. D.—4.00 D. sph.

O. S.—4.00 D. sph.

Treatment—

Given — 4.00 in both eyes for constant wear.

Result—

Patient reported to say that all trouble was relieved.

CASE 8.—Charles T., aet 30. Occupation, Student. Amplitude of accommodation, 1.50 D. Punctum Proximum, 200 m. m. Muscles — 8° insufficiency of the internal recti. Internal recti overcame 25° of prism, base out.

Symptoms—

Indistinct distant vision and inability to read, severe headache after any near work.

Refraction—

O. D.—4.00 D. sph.

O. S.—4.00 D. sph.

Treatment—

Patient was wearing — 4.00 for both eyes which were prescribed for distance and reading, was told to continue wearing — 4.00 for distance and given — 1.00 for reading combined with 3½° prism, base in for reading.

Result—

Good. Some trouble after prolonged near work.

CASE 9.—Chester B., aet 23. Occupation, student. Amplitude of accommodation, 10 D. Punctum Proximum, 100 m. m. Muscles 20°, insufficiency of internal recti. Internal recti overcame 8° prism, base out.

Symptoms—

Very severe headache after near work.

Refraction—

O. D.—. 25 ○ —. 50 cyl., axis 120°.

O. S. —. 50 cyl. axis 15°.

Treatment—

Full correction given and complete tenotomy of external rectus of left eye.

Result—

Over correction of 1°, patient could study well and long, and reported entire relief from trouble.

Case 10.—Raymond P., 13. Occupation, Student. Amplitude of accommodation, 13 D. Punctum Proximum, 77 m. m. Muscles normal. Internal recti overcame 35° prism, base out.

Symptoms—

Had experienced headache after near work and could not shoot well.

Refraction—

O. D.—3.00 D sph.

O. S. Emmetropic.

Treatment—

O. D.—3.00 D. sph.

O. S.—Plain glass.

To be worn for distance only.

Reesult—

Patient returned to say that no more trouble was experienced.

Case 11.—Edgar C., aet 24. Occupation, Student. Amplitude of accommodation, 5 D. Punctum Proximum, 71 m. m. Muscles normal. Internal recti overcame 30° prism, base out.

Symptoms—

Pain when trying to study. Indistinct vision except for near objects.

Refractiom—

O. D.—8.00 D. sph.

O. S.—8.00 D. sph.

Treatment—

Given — 4.00 D. in both eyes, which was gradually increased to the full correction. Given — 4.00 D. in both eyes for reading.

Result—

Good.

CASE 12.—Mrs. S., aet 45. Occupation, Housewife Amplitude of accommodation not taken. Punctum Proximum not taken. Muscles normal.

Symptoms—

Patient could with difficulty do any house-work.

Refraction—

O. D.—15.00 D.

O. S.—Extreme Amblyopia. Myopia not measurable by subjective method.

Treatment—

Given — 6.00 in both eyes and increased till —11.00 was reached. A further increase not accepted.

Result—

Patient could do ordinary work.

CASE 13.—Marion L., aet 23. Occupation, Elocutionist. Amplitude of accommodation, 5 D. Punctum Proximum, 65 m. m. Muscles normal. Internal recti overcame 30° of a prism, base out.

Symptoms—

Patient complained of headache when exposed to a bright light.

Refraction—

O. D. — 10.00 D.

O. S. — 10.00 D.

Treatment—

Patient could use — 4.00 in both eyes for near work with poor illumination, but could not wear stronger lenses without continued and severe headache. Was given a lorgnette with — 10.00 D. in both eyes for distance.

CASE 14.—Nora B., aet 28. Occupation, Housewife. Amplitude of accommodation, 6 D. Punctum Proximnm, 160 m. m. Muscles normal. Internal recti 40° of prism, base out.

Symptoms—

Constant headache becoming unbearable after near work, Pain worse in back of head.

Refraction—

O. D. + 1.50 sph. $\bigcirc$ — 2.25 cyl. axis 180°.

O. S. + .50 cyl. axis 180°.

Treatment—

Full correction given in each eye.

Results—

Headache ceased immediately after using correction.

Case 15.—Nelson G., aet 28. Occupation, Student. Amplitude of accommodation, 7 D. Punctum Proximum, 130 m. m. Muscles normal. Internal recti overcame 30° prism, base out.

Symptoms—

Some pain after continued near work.

Refraction—

— 1.00 $\bigcirc$ — 1.00 cyl. axis 180°.

— 1.00 $\bigcirc$ — .75 cyl. axis 180°.

Treatment—

Full correction given.

Result—

Good.

Case 16.—Moses B., aet 13. Occupation, School Boy. Amplitude of accommodation, 12 D. Punctum Proximum, 150 m. m. Muscles normal. Internal recti overcame 45° prism, base out.

Symptoms—

Headache, unable to study lessons, was considered dull.

Refraction—

O. D. + 4.00 $\bigcirc$ + 3.00 D. cyl. axis 90°.

O. S. + 3.50 $\bigcirc$ + 4.00 D. cyl. axis 90°.

Treatment—

Patient was first given + 2.00 both, which was gradually increased until final correction.

O. D. + 2.00 $\bigcirc$ + 3.00 D. cyl. axis 90°.

O. S. + 2.00 $\bigcirc$ + 4.00 D. cyl. axis 90°.

Result—

Child suffered no more and was soon bright in classes.

Case 17.—James K., aet 20. Occupation, Farm hand. Amplitude of accommodation, 10 D. Punctum Proximum, 150

m. m. Muscles normal. Internal recti overcame 40° prism, base in.

Symptoms—

Had no headache but always knew he could not see as well as others.

Refraction—

O. D. + 4.00 cyl. axis 90°.
O. S. + 5.00 cyl. axis 90°.

Treatment—

Was given full correction.

Results—

Did not return.

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